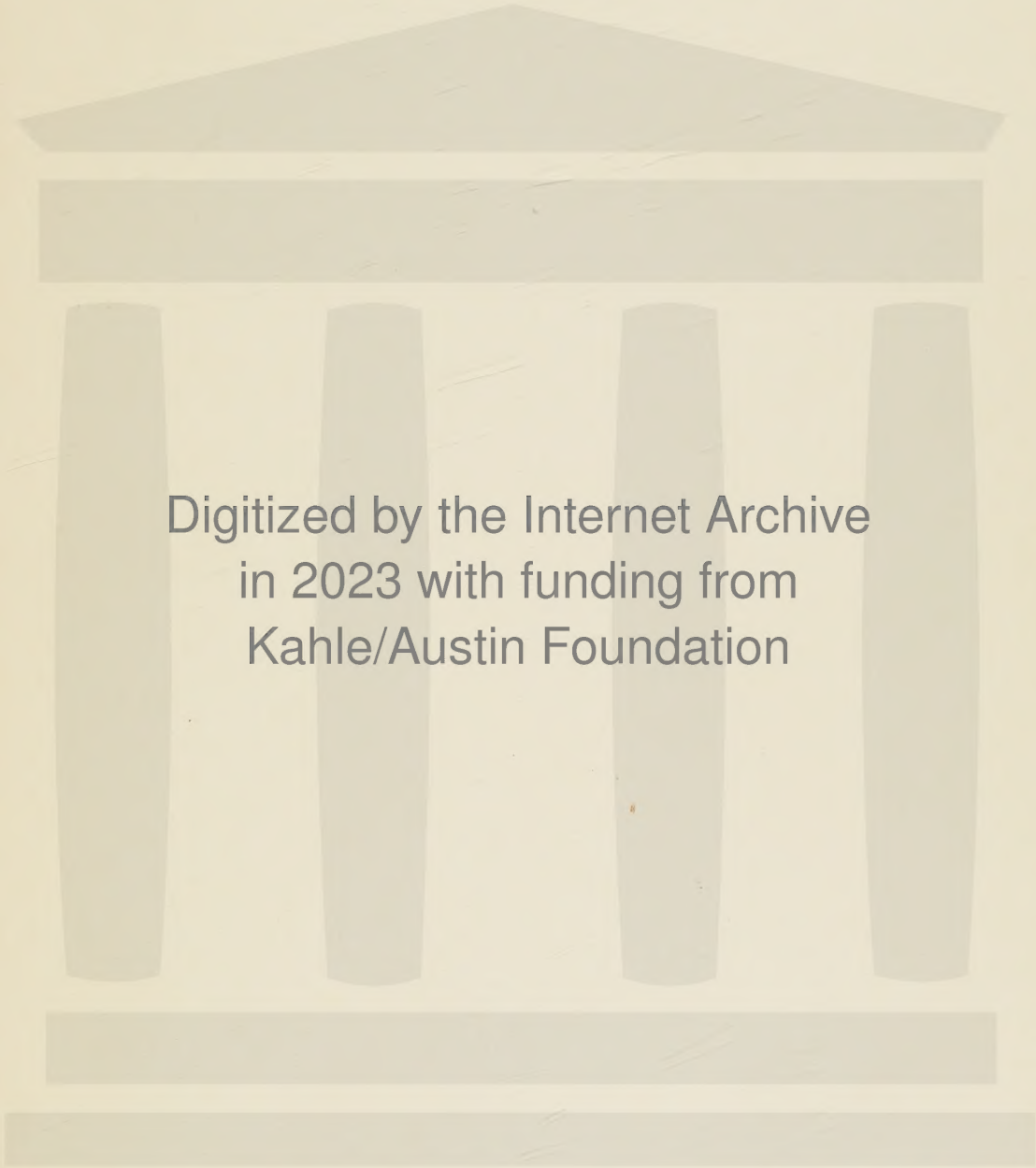
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OF THE

Dominion Astrophysical Observatory

Victoria, B.C.

J. S. PLASKETT, F.R.S., Director

Volume III

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VOLUME III

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PUBLICATIONS

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Dominion Astrophysical Observatory

VICTORIA

Vol. III, No. 1

THE ABSOLUTE MAGNITUDES AND PARALLAXES OF 1105 STARS

BY R. K. YOUNG AND W. E. HARPER

ABSTRACT

General.—The paper presents the results of an investigation into the methods of determining parallaxes by the spectroscopic method and gives individual parallaxes for 1105 stars. These are nearly all of type F to M inclusive, though a few stars of A-type having well defined lines, are also included.

Material.—During the first few years of the Observatory's existence the program carried out was the determination of the radial velocities of several hundred stars from the catalogue of Boss. The present investigation aimed to utilize the spectra, thus secured, for the determination of parallaxes by the spectroscopic method. These spectra were all made with a single-prism instrument giving a dispersion at Hγ of about 29 Angstroms per millimetre. For a very few of them were trigonometric parallaxes available and so a list was prepared of 500 stars with known parallaxes to serve as standards for correlating the line intensities with absolute magnitudes. These were observed with the same one-prism arrangement. Three-prism plates of a few selected stars were also made to study in more detail the changes in the lines affected. The trigonometric parallaxes of these 500 stars were taken from the list of 1646 stars issued by the Mount Wilson observers, being brought up to date by the inclusion of the parallaxes issued since that publication was in press.

Lines Used.—In addition to the five lines used by Mount Wilson a search was made for new ones showing a variation with absolute magnitude and nine such have been made use of. A description of each is given. Several others were found which would serve equally well but complete tables for them have not yet been formed.

Standard Scale.—Considerable attention was given to devising a method of measuring the ratios of the line intensities and artificial spectra having absorption lines of graded intensities were used by each observer so as to keep constantly in mind the value of the step used.

Types.—The types from A to K inclusive were determined afresh by comparing with standard stars for which Harvard and Mount Wilson were in good agreement. Our results agree well with Mount Wilson. The M-types were graded from M0 to M8 according to the strength of the bands. No special class was formed for the Cepheids or c-stars as the curves for these seemed to join on to and form a continuous sequence with the lesser giants.

Empirical Curves.—To obtain the curves relating line intensity to absolute magnitude a series of approximations was performed. For the F, G and K stars the results from such preliminary curves were grouped according to type and absolute magnitudes and proper motion methods applied. The group residuals suggested minor corrections for the final set of reduction tables. The curves found suitable in the late K's were continued on through the M's and seemed to be satisfactory, the slope of the curves being adjusted to suit those stars of type M for which the parallaxes were most reliable. An abridged set of reduction tables relating step value to absolute magnitude is published for every half division of a type so that other observers having similar spectra could easily adapt our results for new work.

Theoretical.—Formulae and graphs are given showing the errors to be expected in the absolute magnitudes for errors which are present in the trigonometrical parallaxes. The latter are useful only in the nearer stars. The well-known formulae connecting the parallax with the *tau* and *upsilon* components of the proper motion are used and a new one devised, based upon radial velocity, total proper motion and the distance of the star from the apex. The formula is $\bar{\pi} = \mu\,(\cdot 089\,V_0^2 + 17\cdot 82\,\sin^2 d)^{-\frac{1}{2}}$ and it is found to be not only quicker to evaluate but gives much more consistent results.

Comparisons.—For 920 of the 1105 stars proper motion data are available to test our results. The 920 stars were divided according to type and absolute magnitude into 50 groups. Each star's proper motion was reduced to what it would have if its apparent magnitude were the mean of the group. The three formulae were used to

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obtain group parallaxes. Our results are compared in table 8 with the magnitudes from the mean of the three methods. This table also gives a comparison of ours with Mount Wilson results for those stars common to both lists. From the proper motion results a small systematic correction of from $-0\cdot2$ to $-0\cdot4$ magnitude should be applied to our late G-type results. Such has not been done, however, pending better methods of procedure now under way. There is substantial agreement between the two observatories except in the giants of late K-type where we have a much greater range. Recently they have found for their M-types some revised magnitudes which are in much better agreement with ours than those previously published.

Probable Errors. The accidental error of a determination from the interagreement of the various lines is $\pm0\cdot15$ magnitude, but based upon the residuals from 128 stars of best determined parallax ($\pi \geqq ''\cdot050$) the probable error is $\pm0\cdot4$ magnitude. This refers for the most part to the dwarfs and is similar to Mount Wilson. For the giants it is hard to get a real test but a comparison is made using 553 stars which are common to both observatories. Taking those differing by one whole magnitude or more, 134 in number—and these are mostly giants—proper motion results as given in table 12 are in general more favourable to our own.

Future Work.—Suggestions for improvement in the work are given.....By measuring all the lines now known to show an effect.....By improving the quality of the spectra through standardization of slit width, development and other factors.....By adopting a more mechanical, though less rapid means of estimating ratios of line intensities.

I—Introduction

The following paper presents the results of an investigation into the methods of determining the parallaxes of the stars by the spectroscopic method. On the completion of the observatory in 1918, the first extended program of observation undertaken was the determination of the radial velocities[1] of several hundred stars from Boss' General Catalogue. It was intended to use the plates taken for radial velocity determinations to obtain the parallaxes by the spectroscopic method then just recently developed by Adams and Kohlschutter.[2] These observers discovered that certain lines in the spectra of the stars showed a marked variation in their intensities between stars of high and low luminosity. Among other lines, they mentioned λλ 4077, 4215, 4290, 4455, 4462, 4494. Before this method could be applied to our spectra, however, it was necessary to obtain empirical curves relating the line intensity in the spectra obtained at this observatory with the absolute magnitudes and this involved the photographing of spectra of stars with known parallax. This work was commenced in 1918.

The general method was planned along the lines discovered by the Mount Wilson observers but several factors seemed worthy of investigation. A search was to be made for new lines which would show a change in intensity with luminosity. It is obvious that the more lines that can be used, at least up to a fairly large limit, the smaller will be the accidental error of measurement for the mean. A casual inspection of the spectra of some stars of known parallax is sufficient to satisfy oneself that fairly large accident departures from normal for any one line do occur. Another point to be investigated was the method of measuring the intensities of the lines. The Mount Wilson observers had adopted the plan of measuring the *ratio* of the intensity in pairs of lines in terms of a unit called a *step*. In the publication of the parallaxes of 1646[3] stars they recognize an intensity ratio as large as ten steps. Considerable work was done here in 1918 in making a standard scale so that the quantity which we called a step might remain constant and be fairly well defined. The construction of this standard and the method of using it will be described in a section by itself. A start was made also in obtaining spectra of stars with known parallax. It was soon discovered, however, that it would be necessary to obtain spectra of a great many stars because the correlation of line intensities to absolute magnitude is

complicated by variations with type also. It is necessary to have a sufficient number of stars to determine the relations for all the types. Moreover, the reliability of the method among the giants seemed somewhat doubtful and as here especially large numbers of spectra are necessary the problem involved a great deal of observation. In the meantime the radial velocity program was pressing and it seemed best to complete this part of the work first. The radial velocity program was completed in 1921 and the absolute magnitude work resumed by the writers conjointly. Each observer has shared equally in the observational part of the program and both have measured all the plates and derived independent reduction curves.

II—Program of Observation

The radial velocity program undertaken in 1918 was compiled from Boss' Preliminary General Catalogue and included 720 stars between the fifth and eighth magnitudes. The basis of selection for these stars was position. We observed all the stars in the even minutes of right ascension north of the equator which had not been previously observed. The odd minutes of right ascension and all stars south of the equator were omitted as these were being observed at Mount Wilson. The basis of selection makes no asumption concerning the proper motions. Only a little over half the stars were suitable for obtaining absolute magnitudes. Moreover for very few of the stars had parallaxes been published and in order to obtain sufficient data we made out an additional program of 500 stars whose parallaxes had been determined at one or more observatories, special attention being given to the modern parallaxes. This latter program is undoubtedly biased in regard to large proper motions for the early parallax observers selected stars with large proper motions as ones likely to yield positive parallaxes. At the same time the great majority of the large proper motion stars have yielded fairly large parallaxes and as these have been used directly the remaining stars which had to be treated by proper motion methods are freer from this objection than they might otherwise be. Moreover, practically all the bright stars of the northern skies are included so that the basis of selection is nearly one of apparent magnitude. In addition to these two programs stars have been observed from time to time from the Harvard Revised Photometry and those of type later than A5 when suitable have also been used.

All the plates have been obtained with the one-prism spectograph and medium length focus camera attached to the 72-inch telescope. This instrument has been described in Volume I, Number 1 and in Volume II, Number 1 of the Publications of the Dominion Astrophysical Observatory so that it is necessary only to give relevant details. The aperture of the collimator objective is 2·5 inches and its focal length 45 inches. The camera lens used has an aperture of 3 inches and a focal length of 28 inches. From May 7, 1918 to August 12, 1919 we used a sixty-degree prism made by Hilger and loaned by Professor Chant of the University of Toronto. Since August 12, 1919 we have used a slightly denser prism of sixty-two degrees angle also made by Hilger. Both these prisms give excellent definition. The latter gives a dispersion at Hγ of about 29 A per millimeter while the first prism gave a dispersion of 34·8 A. On spectra taken with either of these prisms, the iron arc doublets at λ4187 and λ4200, in each of which the

components are separated by about three-fourths angstrom, are clearly resolved with a slit width ·0015 of an inch while the limit of resolution is about one-half angstrom.

Variations in the dispersion and purity of the spectra must undoubtedly have a large effect upon the estimates of line intensity but for our results we may say that the plates have practically all been obtained with the same dispersion. Fully 95 per cent of the parallax stars have been observed with the higher dispersion. For these stars two good spectra were obtained. For the Boss stars six plates were obtained as a rule and while some of these plates were obtained with the slightly smaller dispersion in almost every case two or three spectra were obtained with the larger angle prism also. Stars taken from the Harvard Revised Photometry which have been observed subsequent to the completion of the radial velocity program likewise have been observed with this instrument so that the observational material is fairly homogeneous.

In addition to the one-prism plates we have taken a number of three-prism plates of the brighter stars which have been used to investigate the character of the lines forming the criteria for absolute magnitude.

The problem of obtaining the best available parallaxes for the stars caused us considerable trouble. The observatory did not possess a card catalogue giving all the published data and we felt somewhat hesitant about compiling one because we understood a general catalogue was soon to be issued with an investigation into the systematic errors affecting parallax measures by the various observatories. In 1921, shortly after the August meeting of the American Astronomical Society in California, we received an offer from Professor Frank Schlesinger to place at our disposal parallaxes which he was compiling. These were not ready at the time but as we were in no particular hurry at that time we were pleased to accept his offer. However, these were not available at the time we needed them and we decided to make up our own parallaxes. We examined all the literature available in the observatory and copied out the parallaxes. We were unable to consult all the authorities for very many of the stars. A comparison of our values with those published by the Mount Wilson Observatory in contribution No. 199 frequently showed that they listed more authorities than we could find. It seemed to us also that the weights for the various determinations of parallax, as used by the Mount Wilson observers, were very good and that therefore their parallaxes were superior in most cases to those we were deriving. We decided to accept the Mount Wilson values for the trigonometric parallaxes. In a few cases values for the parallaxes had been published by the Allegheny or McCormick observatories subsequent to the compilation of their list and these we have incorporated to get new values.

III—Lines Used for Absolute Magnitude

The following table contains a list of lines we have used for the determination of absolute magnitude. They include those discovered at the Mount Wilson Observatory and several others.

TABLE I

Ratio	Used in Spectral Types	
	Young	Harper
4071·9 : 4077·9	A2.....M6	A2.....M6
4161·6 : 4167·6	A2.....K2	A2.....K9
4202·2 : 4207·0	G5.....M6	G4.....M6
4215·7 : 4250·6	A2.....K2	A2.....K2
4247·2 : 4250·6	A2.....K2	A2.....K9
4258·5 : 4260·6	F2.....M6	A5.....M6
4271·7 : 4290·1	A2.....G4	A2.....G4
4455·1 : 4462·0	F8.....K9	F8.....K9
4451·1 : 4494·7	G2.....K9	G0.....K8
4455·1 : 4482·4	G6.....M6	G6.....M6
4455·1 : 4489·4	G5.....M6	G6.....M6
4482·4 : 4494·7	M0.....M6	G8.....M6
4489·4 : 4494·7	G5.....M6	G8.....M6
4494·7 : 4496·5	G5.....M6	G8.....M6

Our results indicate that both lines forming the ratios which we have measured show variations with absolute magnitude. We illustrate in figure 1, curves 1, 2, 3, 4 what seems to us would be the result if we could measure the intensity of each line separately. In these curves the ordinates are intensities and the abscissae are absolute magnitudes, the dwarfs being to the right. Curve 1 illustrates a line which shows a rapid change in intensity in the giant stars but which shows less or no variation in the dwarf stars, that is, the curve becomes asymptotic to some horizontal line. Curve 2 illustrates on the other hand, a line which is of little or no use to distinguish between various grades of giants but which is a sensitive criterion for absolute magnitude in the dwarfs. Curves 3 and 4 are still other types of variation. When we measure the ratio of a pair of lines we may get any combination of these types of curves. If the two lines forming the ratio are of

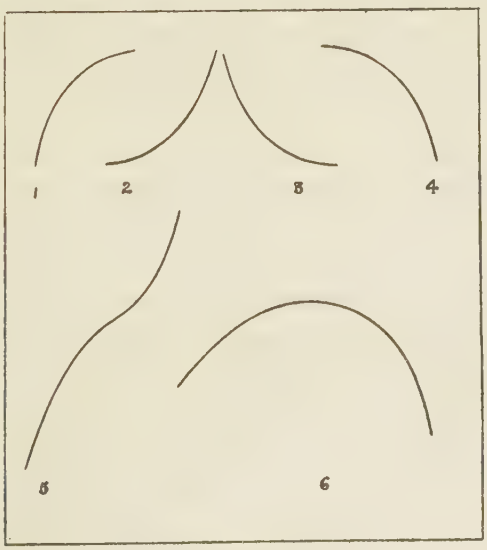


FIG. 1

types 1 and 2, one of the resulting possible curves that we would obtain is shown in curve 5. Curve 6 illustrates what might be the result of measuring the ratio of a pair of lines which behave like curves 1 and 4. Depending on the spectral class where the lines begin to show and the extent of their variations we may get a great diversity of resultant curves connecting the step values for a pair of lines and the absolute magnitude.

We append a description of the behaviour and character of each of the lines used.

λλ 4071 : 77. In the earlier types A5.... these two lines are free from blends. There is a component to the red side of λ4077 but as a rule it is well enough resolved not to interfere with the measures. Both lines become more involved with other lines in the later types and unless the plates are well exposed the estimation of the relative intensity of the lines is subject to a large accidental error. On well exposed plates, however, the variation with absolute magnitude is pronounced over the complete range of spectral types examined. The variation seems to be almost linear. In types earlier than F0 the curves are not well established either for this or the other lines but so far as can be judged from the limited number of A stars which we have studied, this line may be used as a cirterion for absolute magnitude in types as early as A2, provided there are numerous metallic lines present in the spectrum.

λλ 4162 : 68. Like the preceding ratio, the lines in this pair are free from blends in the early type stars but become more involved in the later types. The line λ4162 which is due to strontium, seems to be responsible for the great variation of the ratio in the giants. The ratio is quite reliable in the F– and early G–type stars but is not so good later as some of the stars show rather large residuals and the curve in the extreme dwarfs reverses.

λλ 4202 : 07. The line λ4207 was mentioned by Adams as of possible value as a criterion for absolute magnitude. It does not show very well until the star has reached type G. Both it and λ4202, with which it has been compared, are situated close to other spectral lines and unless the spectrum is fairly strong in that region the measures are unreliable. In the very giant stars the line λ4207 is considerably stronger than the line λ4202 and there is a rapid change in the relative intensity as the absolute magnitude becomes more dwarfish. In the extreme dwarfs, however, the line λ4202 seems to diminish more rapidly than λ4207 and the ratio is not so much positive there as in stars a little more luminous.

λλ 4215 : 50. This pair of lines has been the subject of very careful investigation because it is one of the principal pairs upon which the absolute magnitudes of the giants, as determined by the Mount Wilson observers, rest. The nature of our results for this line can be best studied from our tables published in Section VI but we will describe what we consider the behaviour of this ratio. In types as early as F8 it consists of a curve similar in shape to curve 6, figure 1, though extending possibly less on the descending giant branch. In the dwarf stars λ4215 and λ4250 are almost equal or λ4250 may be even the stronger. As we proceed toward the giants the line λ4215 gains greatly in strength and reaches a maximum somewhere near the absolute magnitude minus one. For the most luminous stars the line loses a little in strength. These characteristics continue in the G–type stars even up to G8 and later but as we come to type K the amount of the turning back is less pronounced so that by the time type K2 is reached the curve

in the giants is almost asymptotic to a horizontal line. For this reason we think that the giant stars of types K3 and later the ratio λλ 4215: 50 is of very little use as a criterion of absolute magnitude. It serves to distinguish a giant from a dwarf but it does not grade the giants properly. The reason for the peculiar behaviour of this ratio is doubtless the complex character of λ4215 Under three-prism dispersion here are two component lines λ4216·4, due to iron, and λ4215·7, the latter itself being made up of the chromium line λ4215·72 and the iron λ4215·60. In giant stars of type F7 like γ Cygni the component λ4215·7 is about 8 times as intense as the component λ4216·4 but the ratio rapidly diminishes in more dwarfish stars. It would seem, then, that the chromium member is the main though not the sole variable and as all three components are blended in our single-prism spectra it is not surprising that, when compared with λ4250, the ratio is not linear.

λλ 4247 : 50. This is a good ratio in the early type stars, especially in the giants, where λ4247 becomes equal to or stronger than λ4250. In the late F-types, such as γ Cygni, there are at least 7 lines which are in general blended in single-prism spectra though occasionally the outlying members are seen separated. The extent of spectrum covered is from λ4244·9 to λ4248·9 and one observer has estimated the ratio of this region to λ4250 whether the former was seen blended or partially resolved. The other observer has considered the stronger portion alone around λ4247·0 the line being ascribed to Sc or Y. This line, strong in the giants in this type, persists in late K dwarfs such as 61 Cygni though greatly diminished in intensity. Three other lines λλ 4248·5, 4247·6 and 4245·5 also persist and one observer has made use of the ratio in the K's while the other has dropped it at K2. In the later type dwarfs the ratio reverses but in spite of these variations and the different methods of treating the line it has been of considerable value giving accordant results.

λλ 4258 : 60. These two lines which are separated by two angstrom units, form a very nice pair for measurement. The ratio seems to vary continuously over a wide range of spectral types. The amount of this variation per absolute magnitude is not quite as great as for some other lines but the accuracy of measurement of lines close together makes up to a large extent for the smaller range shown. This remark applies to the ratio principally in the earlier types. In the later types it shows as large a variation as the other lines used. In the M-types the pair of lines is very clear and sharp and consequently easy to measure.

λλ 4271 : 90. As in the case of λλ 4215 : 50 we have devoted considerable time to this particular ratio. Not only is the iron λ4271 a double but λ4290 consists of two also, viz., λ4289·9 Cr and Ti and λ4290·5 Ti and Fe. In a giant like γ Cygni, F7, both components are about equally strong as seen in three-prism spectra while in a fainter star like η Pegasi, G1, they are still about equally strong though very much diminished in intensity from their previous value. We find, in agreement with the Mount Wilson observers, that the ratio is of use in the early types of all absolute magnitudes but only in the giants of later types. Beyond G4 the variation with absolute magnitude even in the giants seems to be small and as we have several other ratios here which show a large variation we have dropped this pair of lines. Our measures in the M-type giants show that it is of some value but not so good as the other lines we use.

λλ 4455 : 62 *et seq.* The four ratios involving the combination of λ4455 and another line are excellent examples of the combined effect of two lines each of which varies. The line λ4455 is strong in the dwarf stars and for stars of absolute magnitude three and fainter grows in intensity rapidly. In the neighbourhood of absolute magnitude plus one or zero the line shows little diminution with increasing luminosity if it does not grow stronger. The line λ4462 seems to stay fairly constant in the dwarfs and the smaller giants but it grows weaker in the very luminous giants so that the ratio λλ 4455 : 62 is more positive than it is in the less luminous stars. The ratio λλ 4455 : 94 behaves in the same way and to a more marked degree. Both these ratios show curves similar to curve 6 in figure 1 but turned upside down. In contra distinction to the lines λ4462 and λ4494 both of which are weakened in the very greatest giants, the lines λ4482 and λ4489 are strong. Their great increase in strength quite overbalances the small change in λ4455 in these stars so that the ratios λλ 4455 : 82 and λλ 4455 : 89, both of which are very positive in the dwarfs, decrease steadily as we pass to more and more luminous stars. It should be observed that the line λ4489 is complex, four components usually forming a blend on single-prism spectra. They are λλ 4491·0, 4490·1, 4489·1 and 4488·4, the low temperature iron one at λ4490·1 giving the character to the blend.

λλ 4482 : 94. From what has been said of these two lines in the preceding paragraph it follows of course that this pair must show a small variation, which they do. In the giant stars of class K2 to M6 both the lines are clear and easy to measure which compensates partially for the smaller range shown.

λλ 4489 : 94. It was mentioned in the discussion of the ratios beginning with λ4455 that the line λ4489 was very strong in the giants and that the line λ4494 became weak. This pair, therefore, makes a fine ratio for the giants and supergiants. It becomes negative as we pass to the dwarfs and reaches a minimum somewhere between absolute magnitudes plus two and plus four. For the extreme dwarfs it is more positive again. Another logical pair to measure would be the ratio λλ 4462 : 94 which must also show a good result in the supergiants. These various combinations are, however, not all independent.

λλ 4494 : 96. The lines forming this pair behave much the same way as the preceding pair. They are very easy to measure in the late types and the accidental error of measurement must be small. The line λ4496 consists of two as seen in three-prism spectra, viz., 4497·03 Cr and λ4496·23 Ti and while the variation is the sum of that in each yet the major portion seems to be due to the violet member of the close pair.

In addition to the lines so far discussed as showing a variation with absolute magnitude each observer has noted lines from time to time that give promise of being useful. Among others may be mentioned λλ 4233, 4305, 4348, 4395, 4444, 4474, 4522 and 4531. Some of these were measured against other suitable lines but complete tables were not formed and they do not appear in our results. Most of them are enhanced lines principally of titanium. The one at λ4444 is in reality a blend of 5 components the important ones being those of titanium. This line has been used by Lockyer against λ4455 in similar work and it should give satisfactory results. The inclusion of all the lines now known to vary would lead, we think to a still further reduction of the accidental errors.

The question of weighting the results from the various lines has been the subject of considerable thought. Some of the factors which should enter into the weight are:

1. The number of plates on which a line was measured.
2. The number of times a line was measured.
3. The exposure and definition of the plate.
4. The slope of the reduction curve connecting line intensity with absolute magnitude for that line.
5. The reliability of the line as judged from the average residual left from many stars.

The system of weighting, if it were logical, would have to be very complex. We have no doubt that such a system could be worked out and would improve the mean but it seemed to us hardly worth while and we have adopted the procedure of taking straight means. In a few cases if a line seemed to give very discordant results or was uncertain it has been omitted or given half weight.

IV—The Standard Scale

An artificial spectrum was made showing absorption lines graded in intensity by uniform steps, the weak lines at one end and the stronger lines at the other. The standard was made as follows. A piece of opal glass was illuminated by an electric light and masked so that when viewed from the side away from the light an opening about one centimetre by ten centimetres was visible. In front of this opening and running at right angles to its length were placed twenty small wires one-half millimetre in diameter and four centimetres long. A camera was used to photograph the illuminated opening being placed at a distance such that the length of the image of the illuminated opening was seven millimetres. The images of the wires which show as absorption lines were about ·04 of a millimetre wide. This is about the width of a good spectrum line when photographed with a one-prism spectrograph giving a dispersion of 30 A at Hγ. An exposure of sixty seconds was given and then the end wire was removed and the exposure resumed for six seconds when the second wire was removed. The following exposures, expressed in seconds, were made, one wire having been removed between each.

60, 6, 7, 7, 8, 9, 9, 11, 12, 13, 14, 15, 17, 19, 21, 23, 25, 27, 30, 33, 37.

The plate was developed and the lines showed a good gradation in intensity, the faintest being just visible and the strongest clear and sharp, a very good match for some of the best spectral lines. Several trials were made and two scales finally selected, one of which was used by Young and one by Harper (see Plate III). In each of these scales the line width is about the same but the latter's scale shows a greater change per step.

Considerable experimenting was done also in an attempt to obtain a standard which would measure both intensities and widths. It was found too difficult, however, to reproduce the characteristics of spectral lines and the method was finally abandoned for the simpler procedure.

In using the standard scale we do not attempt to match a line of the scale with a line in the spectrum. The standard scale is placed over the plate to be measured so that the artificial lines are beside those to be measured in the stellar spectrum and the mental picture of the relative intensity of the two stellar lines is carried over and equated to an equal ratio in the standard. The problem is to find a pair of lines in the standard scale

which give the same intensity ratio as the two lines in the spectrum. It is convenient and probably the best procedure to select lines in the standard of about the same absolute intensity as the spectral lines and this can usually be done. This procedure is very much simpler than to attempt to find a line which matches in every way any given spectral line. In this latter case, the character of the edges of the line and its width enter. In the adopted procedure the comparison is always made between lines of the same character.

The constancy of the standard and the reliability of the method of measurement have been checked from time to time by remeasuring a number of stars and comparing the results. It has been found that even after comparatively long intervals one returns to the same values. Further, both scales have been used for the same stars by the same observer and the measures agree very well when the proper conversion factor has been applied to change from one scale to the other. We think that any other observer could use the curves we have derived connecting line intensity and absolute magnitude by making a similar scale and measuring a comparatively small number of stars to find the step value of the scale. It would be essential, however, to use spectra taken with an instrument giving about the same dispersion and purity as the spectrograph attached to he 72-inch telescope.

Figure 2 gives a graphical comparison of the step values obtained by the two observers from the same stars each using his own standard scale. In this curve the ordinates are steps on the scale used by Harper and the abscissae are steps on the scale used by Young. This curve would enable either observer to use the empirical curves connecting absolute magnitude and line intensity constructed by the other. If for instance for a certain pair of lines in a star Harper obtains an intensity difference of 6 steps he might convert this into an absolute magnitude by using 6 steps on his own curves or 13·3 steps on Young's. Conversely, if Young obtained 15 steps for the same pair of lines he might convert this into an absolute magnitude by using 15 steps on his own curves or 6·8 on Harper's. The shape of the curve depends primarily on the character of the standard scales but to a small extent it depends on the observer. That this is true can be seen from a comparison of figures 2 and 3. Figure 3 is a comparison of the two scales when used by the same observer for a number of lines.

There is very little difference in the curves of figures 2 and 3 for steps below eight on Young's scale but for larger steps the difference increases till it is quite marked. The fact that two observers may use the same scale somewhat differently does not vitiate what has just been said about the practicability of either observer being able to convert his measured values to fit the empirical curves of the other.

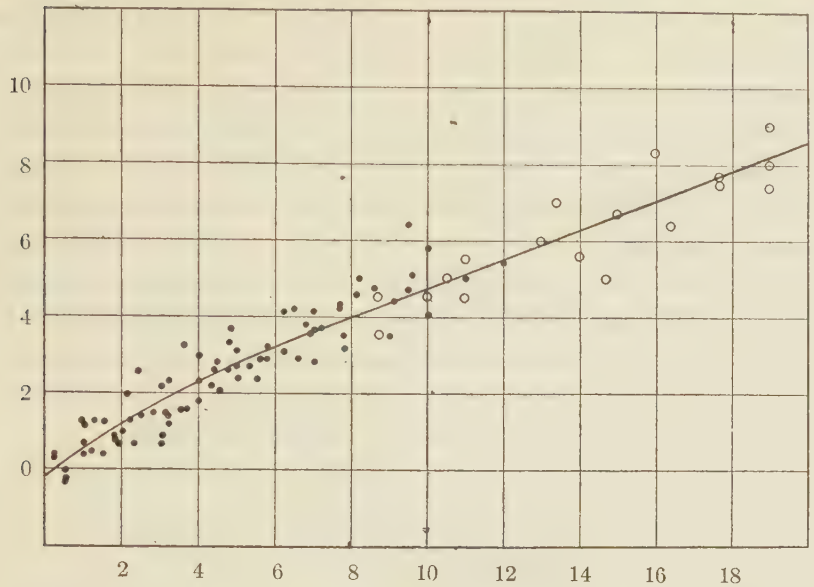


FIG. 2. Curve showing measured steps for a few stars from Harper's and Young's measures each using his own scale. Ordinates are Harper's values, abscissae are Young's values.

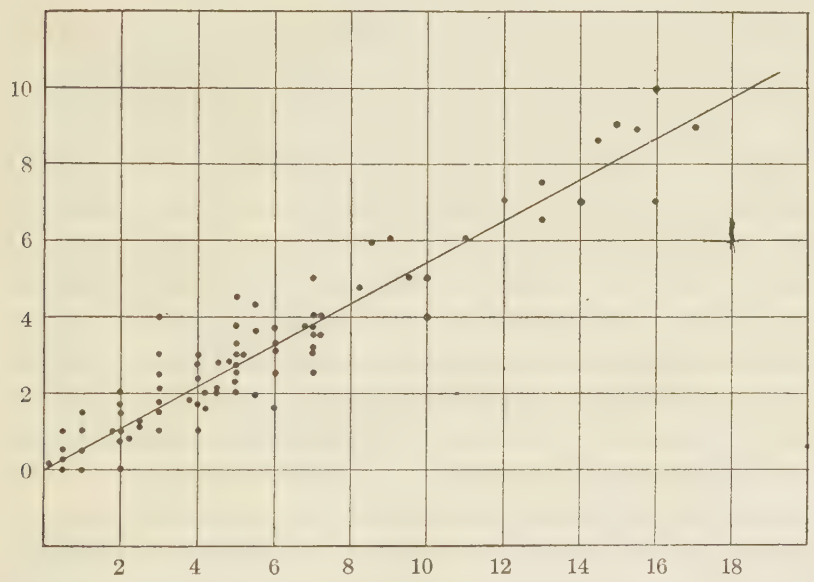


FIG. 3. Curve showing measured steps for a few stars when both scales were used by one observer. Ordinates are the measures using Harper's scale and abscissae are the values using Young's scale.

V—The Determination of the Types of the Stars

For most of the Boss stars and all the H.R. stars on our list no types were available save those given by the Harvard College Observatory. The experience of the Mount Wilson observers showed that the types as listed in the H.R. catalogue were subject to a fairly large accidental error and it seemed worth while to redetermine the types of the stars we were using. For some time we measured pairs of lines according to the method

followed by the Mount Wilson observers[3] but later discarded this method for the simpler procedure of eye estimates. The reasons for this were several. In the first place the measures of any pair of lines for type need a correction for absolute magnitude and the time spent in estimating several pairs of lines and reading values from curves was very much greater than direct eye estimates while the latter seemed sufficiently accurate. In the second place, the effect of any small error in the type did not seem to alter the absolute magnitude derived for the star because we use a rather large number of lines. The usual tendency of an error in the estimation of the type was to make the agreement of the absolute magnitude derived from the various lines a little poorer without altering the mean very much. Besides, any small error in estimating the type of the stars by an eye estimate comes not so much from the lack of sensitiveness to spectral differences as to the indefinite nature of the Harvard definitions of spectral types.

The difficulty arises from the multiple nature of the Harvard criteria which are often contradictory. Thus we are told that in type A5 "the calcium line K is 0·9 times as intense as the compound line H and H_ϵ and more intense than H_δ. Line 4481·2 is no longer the most conspicuous among the solar lines." As a matter of fact if one takes the intensity of the calcium K line as a criterion one can find A5 stars showing scarcely any metallic lines whatever and on the other hand in many stars in which the calcium line K would place them in class A0 or A2, the metallic lines are very numerous and fairly strong. In the later types the Harvard criteria pay special attention to the hydrogen lines, the G band and the calcium line λ4227, all of which show variation with absolute magnitude. An inspection of the absolute magnitudes of the F-type stars shows that they are affected by this factor. Among the early F-types there are no stars as dwarfish as 5·0 or 6·0. The reason for this seems to be that in the very dwarf stars the hydrogen lines are weakened and the calcium line λ4227 is strengthened which favours the star being placed among the later types. The presence of small inconsistencies in the Harvard classification has been recognized for some time and the International Committee on Stellar Classification[4] remarks:—"It is evidently ultimately desirable that each spectral class should be precisely defined, both by verbal description and by means of standard stars. The present moment, however, does not appear opportune for doing more in this way than has already been done at Harvard." It seems to the writers that if the system is to be definite the multiple nature of the criteria must be abandoned.

For our purpose all we wished was a system which would agree with the Harvard scale on the whole and which would enable us to place each star in a definite place in that scale. For types earlier than F we have used the ratio of the K line to H_δ or H + H_ϵ as given by Harvard for the various divisions. If the star was definitely F0 or later, we shifted the attention to the ratio of the lines λ4227 and Hγ. These lines are about equal to each other in F8. For stars later than F8 we used the absolute strength of the line λ4227 up to and including K9 stars. The line λ4227 reaches its maximum strength about K9 or M0 and in the late M-types is much weaker. If our criteria showed the star as late as K5, we looked for the presence of the titanium oxide bands and when these were present the star was placed in class M. If the titanium oxide bands were not present the star was placed in the K-type, its exact place being fixed by the strength of the calcium line λ4227. We have chosen stars as typical of the various classes.

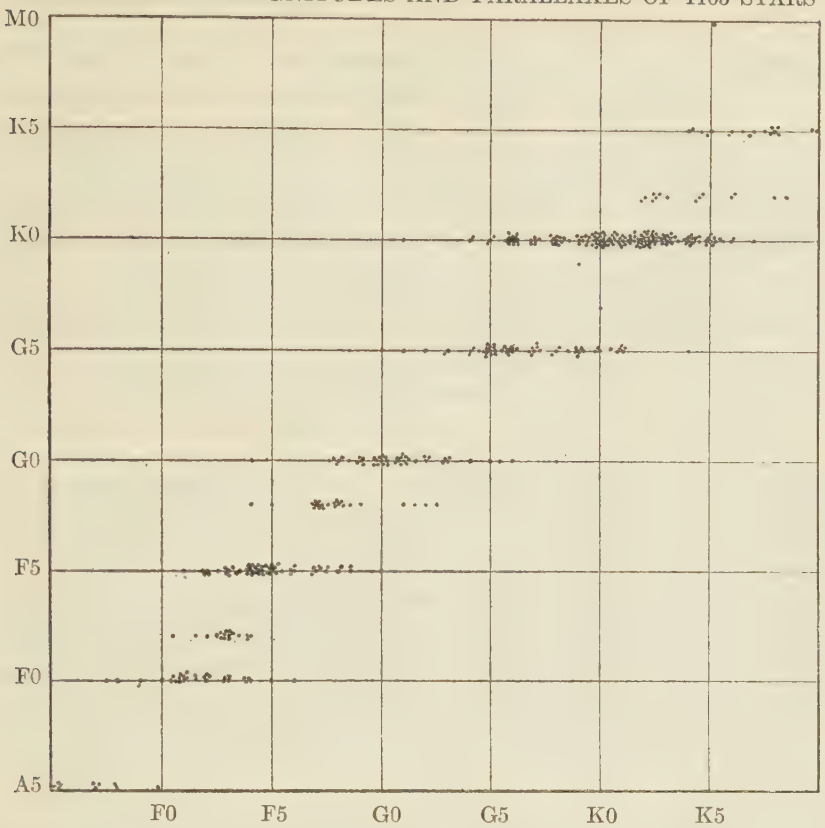


FIG. 4. Plot of the Harvard and Victoria types in the first twelve hours of right ascension. Ordinates are Harvard values and abscissae are Victoria values.

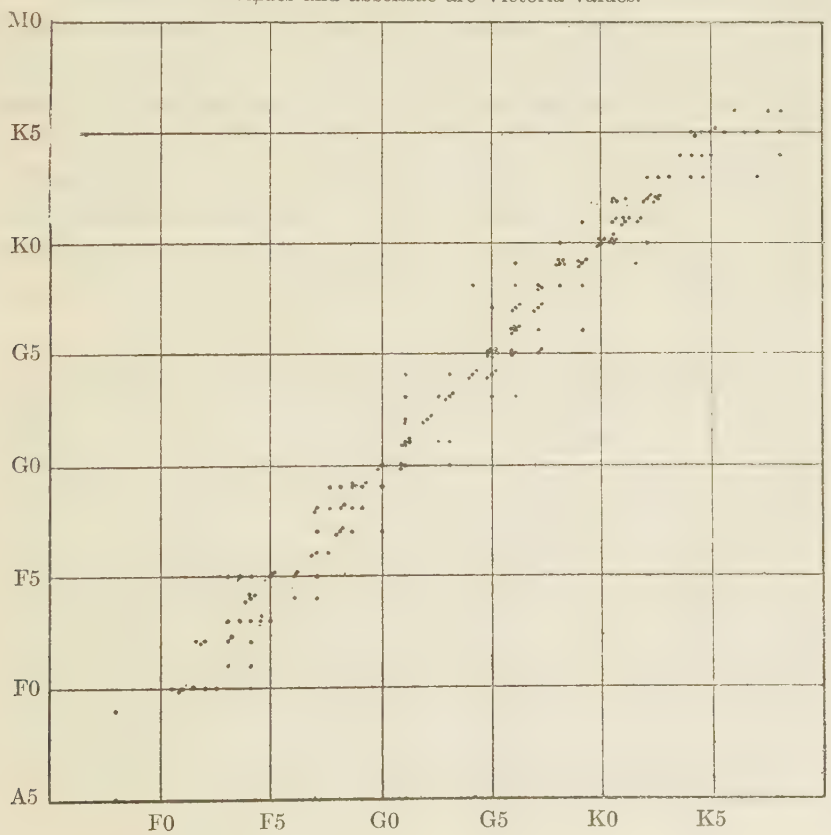


FIG. 5. Plot of the Mount Wilson and Victoria types in the first twelve hours of right ascension. Ordinates are Mount Wilson values and abscissae are Victoria values.

On one plate (see Plate II) we have photographed, Vega A0, 101 Herculis A3, 15 Vulpeculae A5, ν Herculis F2, γ Serpentis F7. On another plate (see Plate III) we have photographed ζ Herculis G1, β Boötis G5, α Boötis K0, π Herculis K3, γ Draconis K5, δ Ophiuchi K9 and α Herculis M6. In addition to these we have chosen the following stars as typical of the various subdivisions in the M-types for which we used as a criterion the strength of the titanium oxide bands, β Andromedae M0, α Orionis M1, η Geminorum M2, β Pegasi M3, α Herculis M6, R Lyrae M7, and 45 Arietis M8. (See Plate IV). Figures 4 and 5 show a graphical comparison of our types with those determined at Harvard and Mount Wilson. The ordinates are the Harvard magnitudes in figure 4 and the Mount Wilson magnitudes in figure 5, while in both the abscissae represent our own types.

The agreement of the Mount Wilson and the Victoria types is very good. In the early F-types we estimate one or two-tenths later and in the very late K-types we have several stars which we call K7 to K9, whereas very few stars in the Mount Wilson types are later than K5. Otherwise the agreement is almost perfect and the accidental error of both systems is satisfactorily small. As was pointed out before, we have made our criteria for type as simple as possible and we think that the small probable error which the types show, together with the fact that the division into types is perfectly definite, should go a long way toward establishing the simple criterion as a basis for selection of type.

The curve showing the relation of our types to the Harvard is not very satisfactory. Part of the lack of agreement may be due to the fact that the Harvard classification does not recognize all the intermediate types and part may also be due to errors in proof reading or printing. Part may also be due to the divergence of the criteria we use from that employed at Harvard but inasmuch as our types are almost always in exact agreement with the Mount Wilson values and have been arrived at by independent methods, we think that the main cause of the differences found for most of the stars is accidental error. The comparison shown in figure 4 rests on the stars in the first twelve hours of right ascension. It seemed to us that the plot of the next twelve hours on the same sheet would only confuse the appearance of the diagram without altering the salient features.

Before leaving the discussion of the types of the stars we refer to the class with the *c*-characteristic. In the original classification of these stars by Miss Maury they were associated with sharp lines. We doubt if this is their distinguishing characteristic for many of our very dwarf stars have the very finest lines and the spectrograph attached to the 72-inch telescope gives fine spectra. The lines in the c-stars are marked by strong absorption and fair width, consequently in spectra taken either with low dispersion or with high dispersion, if the purity is not great such as in objective prism spectra, they would appear sharper than the finer and weaker lines in the more dwarf stars in which the lack of purity would decrease the contrast of the absorption lines. The fact that these stars have always been associated with sharp lines is particularly misleading at the present time when the density in the c-stars is known to be low and one is inclined to ascribe the narrow character of the lines to the low density.

VI—The Determination of the Empirical Curves Relating Line Intensity to Absolute Magnitude

There are approximately 500 stars in our list whose parallaxes have been measured and it is these stars that we have used for obtaining the curves relating line intensity to luminosity. It will be sufficient if we show the procedure for one of the lines as all have been treated alike. The stars were first divided into groups containing on the average about ten stars though some groups contained as few as four and one contained 33. The basis of division into groups was type and absolute magnitude. In any group the range in the types was about one-half a main spectral division and the range in absolute magnitude was confined, so far as we could determine it from parallax or from the spectroscopic values already published, to about one magnitude. In the case of the nearby stars the trigonometric parallax gives good individual values for the absolute magnitudes but for the giants whose parallaxes are small these are unreliable and we adopted the mean of the trigonometric and the spectroscopic as an indication of the group to which to assign the stars. The reasons for this procedure are more fully outlined in section VII. The mean of the ratios of the intensities for the stars in the various groups was formed and plotted against the mean absolute magnitude. In forming this mean we used the spectroscopic absolute magnitude of the Mount Wilson observers. It would have been more consistent probably to have used the same values as used for assigning the stars into groups but at the time we placed most dependence on the spectroscopic values. As a matter of fact it makes very little difference in the mean values whether we used the Mount Wilson values of the trigonometric or those derived later from proper motion because the means for the groups from all three sources are in substantial agreement. This part of the work too was very preliminary and has little effect, as will be seen later, on our final results. The result of this plot for the line λλ 4071 : 77 is shown in figure 6. The ordinates are steps and the abscissae are absolute magnitudes. Each circle represents the mean of a number of stars forming a group. This number and the mean type for each group is indicated in the figure.

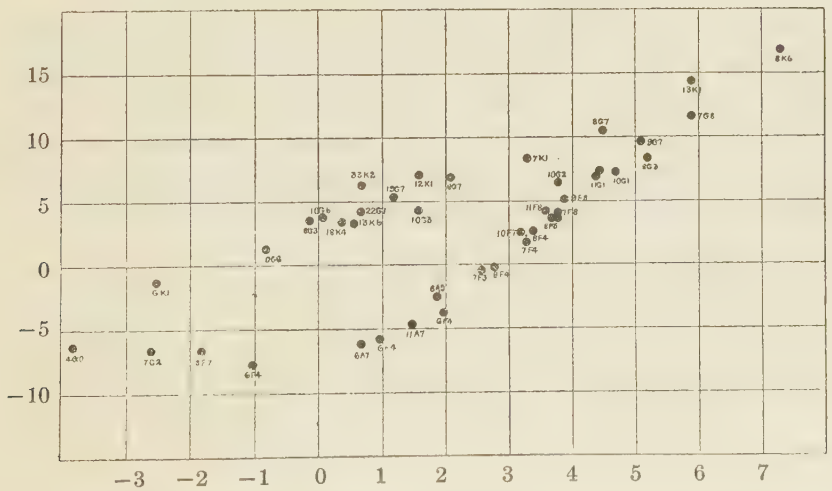


Fig. 6. Preliminary Relation of Line Intensity to Absolute Magnitude 4071:77

The graph enabled us to obtain a preliminary idea of the variation of the line with type as well as with absolute magnitude but because each group contained a fairly wide range in types the variation with this factor is not well shown. To obtain the variation with type more definitely we redivided the groups making the limits for the types in each group narrow and including wider limits in the absolute magnitudes. The limits chosen were about two-tenths of a Harvard spectral division and two absolute magnitudes. By means of the curves just drawn, the mean step value for each of these new groups could be reduced to what it would have been had the mean absolute magnitude for the group been the nearest integer. In this way we obtained the curves shown in figure 7 giving more clearly for each absolute magnitude the change in line intensity with type for the pair of lines λλ 4071 : 77.

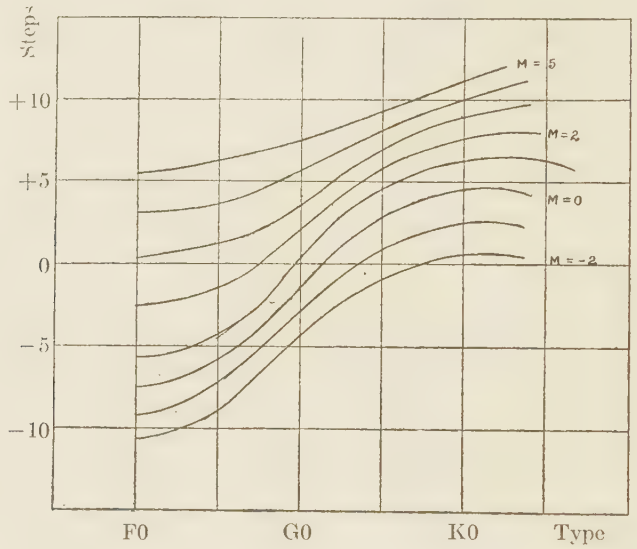


Fig. 7. Relation between Type and Line Intensity 4071:77

For each of the forty-nine groups of stars we next computed a new absolute magnitude as outlined in Section VII and co-related these with the mean step values for each line and each group. Columns one to four of Table 2 give the results of this computation for the line λλ 4071 : 77. Column one gives the numbers of stars in the group and column two gives the mean type as determined here. Column three gives the mean absolute magnitude which we assigned to the group, while the fourth column gives the mean step value of the ratio λλ 4071 : 77 for the various groups.

TABLE 2

No. of Stars	Mean Type	Victoria M	Mean Step	Reduced to F8	No. of Stars	Mean Type	Victoria M	Mean Step	Reduced to F8
7	G1·9	+5·80	+ 8·4	+7·0	5	F4·0	+2·60	− 6·0	− 4·3
7	G7·4	5·46	+10·5	+7·2	9	G6·0	−0·90	+ 1·2	− 5·1
10	G2·8	2·97	+ 4·3	+1·1	6	A7	+0·60	− 6·1	?
7	G8·0	6·23	+11·6	+8·1	11	A7	+2·01	− 4·6	?
10	G6·1	1·38	+ 3·8	−3·0	8	A8	+2·69	− 3·8	?
10	G2·0	3·85	+ 6·9	+4·9	8	F4·0	+2·36	− 3·8	− 1·9
10	G1·2	4·77	+ 7·2	+6·1	7	F3·0	+2·90	− 0·4	+ 1·3
7	G7·1	3·32	+ 6·9	+1·7	10	F4·0	+2·58	− 0·3	+ 1·4
9	G6·9	5·09	+ 9·6	+6·5	4	G0·5	−2·46	− 6·3	− 8·6
19	G7·0	1·09	+ 5·4	−2·1	8	F7·5	−2·95	− 6·6	− 6·1
11	G0·9	4·43	+ 6·9	+5·7	7	G2·0	−2·99	− 6·6	−10·0
7	F4·7	4·63	+ 3·6	+4·6	6	F4·0	−0·70	− 7·7	− 4·5
8	F4·2	4·18	+ 2·6	+3·8	22	G7·0	+0·10	+ 4·2	− 2·8
7	F7·3	3·75	+ 3·6	+4·0	6	K0·5	−4·14	− 1·2	?
10	F6·8	3·33	+ 2·5	+3·1	6	K0·5	+3·79	+ 8·2	?
6	F4·3	3·23	+ 1·7	+2·8	9	K1·0	+2·04	+ 7·0	?
10	F7·6	3·90	+ 4·2	+4·4	3	K6·0	+7·40	+16·8	?
7	F8·4	5·17	+ 7·3	+7·2	16	K4	−1·08	+ 3·4	?
9	F7·7	4·81	+ 5·1	+5·2	12	K1	+5·98	+14·4	?
11	F7·6	+4·34	+ 4·1	+4·2	8	K6·5	+0·60	+ 3·3	?
8	G3·0	−0·46	+ 3·5	−1·2	3	K2	+0·50	+ 6·2	?

The various groups shown in table 2 are not very well suited as they stand for obtaining the desired curves for each spectral type because the mean types for the various groups are fractional. The preliminary curves we have drawn giving the approximate variation of line intensity with type enable us to reduce the step values found for the various groups to what they would have been for closely neighbouring types. Column 5 in Table 2 shows the reduction of many of the groups to the type F8. The values in this column are plotted in figure 8. The open circles represent groups of stars that had to be carried forward or backward a considerable number of type divisions and should, therefore, be given less weight than the filled circles which represent groups of stars comparatively near F8. The curves relating line intensity to type did not seem to us to be sufficiently trustworthy to justify us in carrying the A-type groups as far forward as F8 or the K-types backward. A curve drawn through the points in figure 8 represents a preliminary curve for type F8 showing the variation of the line λλ 4071 : 77 with absolute magnitude. This curve is now based almost wholly on our own absolute magnitudes as opposed to the first curves drawn which rested on the Mount Wilson absolute magnitudes. Curves were drawn for each four-tenths of a main spectral division from F0 to K6. We had to employ a certain amount of smoothing out process in order that the curves would show a continuous variation from type to type which we assumed they should do.

80600—2½

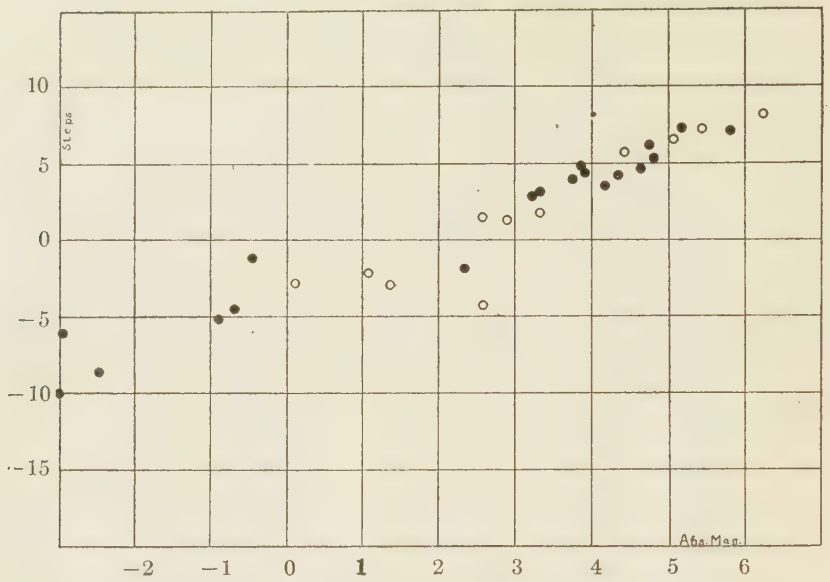


Fig. 8. Preliminary Curve showing Relation of Line Intensity to Absolute Magnitude for pair 4071:77, Type F8

Absolute magnitudes were computed for all the stars with the aid of the preliminary reduction tables and the mean for the groups taken. If this was not in agreement with the absolute magnitude for the group which we had derived either from trigonometric parallaxes or proper motion data as outlined in Section VII, we assumed that our curves led to systematic errors and we corrected each of our absolute magnitudes by this amount. We considered that we would arrive in this way at a set of absolute magnitudes which would be systematically the same as our original material and which would have a much lower accidental error than affected the original ones because our values were based on a considerable number of lines. This would be especially true in the small parallaxes. In the parallaxes as large as one-tenth of a second or a little less, if they had been observed several times, we still considered the trigonometric parallaxes superior.

TABLE 3

—	No. of Stars	Mean m	Type	M Adopted	Mean Trig. π	M from Trig. π	Mt. W. M	Young M	Harper M
1	6	4·02	A7	0·60	·012	0·60	0·75	1·00	1·37
2	11	4·65	A7	2·01	·026	1·70	1·44	1·93	1·98
3	8	4·41	A9	2·69	·050	2·89	1·90	2·46	2·24
4	6	3·85	F4	−0·70	·011	−1·00	−1·00	−0·23	−0·13
5	8	3·75	F7	−2·95	·013	−0·70	−1·76	−1·56	−1·61
6	4	4·00	G0	−2·48	.....	.....	−3·80	−2·25	−2·16
7	7	5·23	G2	−2·99	·007	−0·50	−2·60	−3·17	−2·73
8	8	3·85	G3	−0·46	·014	−0·30	−0·15	+0·91	+0·68
9	6	5·00	F4	2·60	·002	−3·50	+1·00	+0·93	+1·07
10	8	4·11	F4	2·36	·035	+1·80	+2·00	+1·61	+1·71
11	7	5·27	F3	2·98	·023	+2·00	+2·64	+2·53	+2·77
12	10	5·30	F4	2·58	·036	+3·10	+2·76	+2·90	+3·00
13	7	4·96	F4	3·23	·052	+3·50	+3·20	+3·46	+3·41
14	8	4·70	F4	4·18	·085	+4·30	+3·40	3·68	+3·46
15	8	6·10	F5	4·60	·058	4·90	3·76	3.96	+3·70
16	10	4·97	F7	3·33	·040	3·97	3·21	3·57	+3·35
17	11	5·15	F8	3·97	·044	3·40	3·54	3·91	+3·87
18	8	5·38	F7	3·75	·054	4·00	3·58	3·84	+4·00
19	11	5·60	F8	4·34	·058	4·40	3·83	4·16	+4·06
20	9	5·96	F8	4·81	·062	4·80	3·95	4·27	+4·20
21	7	5·27	F8	5·17	·106	5·14	4·90	5·03	+4·53
22	10	4·76	G3	2·97	·029	2·00	1·82	1·96	+2·10
23	10	5·32	G2	3·87	·055	4·00	3·82	3·76	+3·48
24	11	5·20	G1	4·44	·072	4·47	4·40	4·67	+4·36
25	10	5·50	G1	4·77	·078	4·96	4·70	4·68	+4·66
26	8	6·26	G3	5·75	·081	5·80	5·30	5·00	+4·84
27	9	3·70	G6	−0·90	·016	−0·34	−0·79	−0·25	+0·08
28	10	4·53	G6	1·43	·017	+0·60	0·11	+0·77	+0·91
29	22	4·27	G7	0·15	·017	+0·40	0·68	+1·00	+1·28
30	19	4·72	G7	1·09	·032	+2·23	0·11	+1·46	+1·58
31	8	5·05	G7	3·32	·047	+3·42	2·21	+2·10	+2·04
32	8	5·50	G7	5·46	·055	+4·20	4·34	+4·30	+3·42
33	9	5·77	G7	5·09	·079	+5·26	5·10	+4·88	+5·11
34	7	5·46	G8	6·23	·159	+6·48	5·86	+5·90	+5·74
35	6	4·15	K1	−4·14	·008	−1·45	−2·50	−3·35	−2·93
36	18	3·67	K3	−1·08	·002	− 4·7	0·34	−0·20	−0·03
37, 38	33	4·15	K2	0·52	·022	+0·87	0·62	+0·80	+0·88
39	13	4·49	K6	0·60	·026	+1·54	0·57	−0·10	+0·05
40	12	5·02	K1	2·04	·038	+2·90	1·42	1·77	+1·28
41	7	5·43	K1	3·79	·034	+3·05	3·10	2·04	+2·20
42	13	5·77	K1	5·98	·124	+6·24	5·87	5·71	+5·63
43	8	5·44	K6	7·40	·203	+7·00	7·58	7·43	+7·55

Table giving the Mean Absolute Magnitudes derived for the various groups of stars, types A5-K9

Column five in table 3 gives the values of the absolute magnitudes we adopted as best for the various groups of stars from types A5 to K9 and also the mean values derived for the same groups from our curves by both Young and Harper.

We were now in possession of a preliminary absolute magnitude for each of our standard stars whose accidental error we believed was fairly small. The great advantage

in having individual absolute magnitudes was, that the groups could be dispensed with and each type of star treated separately. We plotted the individual measures of line intensity and these new absolute magnitudes for each tenth of a spectral type. In order to increase the data the types were overlapped, that is to say, for the F1 curve we plotted all the stars of types F0, F1, F2; for the stars of type F2 we plotted F1, F2, F3; etc. The result of this work did not as a rule result in very drastic changes to the original curves but it did enable us in some cases to correct small errors which had crept in by the method of forming group means.

An abbreviated set of reduction tables for both Young and Harper is shown in Tables 4 and 5. In our unpublished tables every tenth of a spectral subdivision is listed and the arguments are the type and step values while the body of the table consists of absolute magnitudes. This latter method is the most convenient for use but has the disadvantage for publication that for several lines there are two absolute magnitudes corresponding to one step value. To overcome this difficulty we have made the arguments type and absolute magnitude while the body of the table consists of the corresponding step differences. We have listed the step values corresponding to every second absolute magnitude only in order to reduce the size of the published tables. With few exceptions the tables might be expanded again. Any student who desires to study further the accidental and systematic errors which affect our results will be in a position, with the help of these tables and the absolute magnitudes published for each line, to reproduce our measured step differences for any star.

TABLE 4

	F0					F5					
M	4071 77	4215 50	4271 90	4247 50	4162 68	4071 77	4215 50	4271 90	4247 50	4258 60	4162 68
7·0	+ 8·8	.....	.....	.....	.....	+ 9·2	.....	.....	.....	.....	.....
5·0	+ 3·5	− 1·5	+ 1·5	− 3·7	−10·0	+ 5·0	− 0·5	+ 6·0	− 5·8	− 9·6	− 9·8
3·0	− 1·8	+ 1·8	− 3·0	− 1·0	− 4·0	+ 0·5	+ 3·3	+ 1·6	− 3·3	− 5·8	− 4·0
1·0	− 7·2	+ 4·8	− 5·6	+ 1·7	+ 1·7	− 3·8	+ 6·5	− 2·1	− 0·6	− 3·4	+ 1·5
−1·0	−12·9	+ 8·6	− 8·4	+ 4·5	+11·0	− 8·2	+ 9·3	− 4·5	+ 2·0	− 1·0	+ 6·7
−3·0	.....	+12·0:	−11·0	+ 7·2	.....	−12·1	+ 8·6	− 7·0	+ 4·7	+ 1·0	+12·0

	G0							G5									
M	4071 77	4215 50	4271 90	4455 62	4247 50	4258 60	4162 68	4071 77	4215 50	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4489 94	4494 96	4455 89
7·0	+11·0	.....	.....	+ 5·5	.....	.....	.....	+13·2	− 5·3	+ 4·8	+9·2	.....	.....	−16·0	.....	.....	.....	.....
5·0	+ 7·4	0·0	+ 7·2	+ 1·7	− 9·6	− 7·8	− 9·5	+ 9·6	+ 1·0	+ 0·6	+6·2	−14·7	− 8·8	−11·9	.....	.....	.....	.....
3·0	+ 3·8	+4·4	+ 4·7	− 0·6	− 6·6	− 5·3	− 5·0	+ 6·7	+ 4·5	− 2·1	+3·0	−11·0	− 6·3	− 9·0	+13·0	−10·8	+ 9·8	+15·0
1·0	+ 0·2	+7·8	+ 1·9	− 2·0	− 3·7	− 3·6	− 3·0	+ 3·2	+ 7·6	− 3·7	0·0	− 7·5	− 4·5	− 7·0	+ 7·8	− 8·2	+ 5·4	+ 9·2
−1·0	− 3·4	+11·0:	− 1·0	.....	− 0·9	− 2·0	− 1·0	− 0·3	+11·0	.....	+2·6	− 4·0	− 2·6	− 2·6	+ 3·0	− 4·8	+ 1·2	+ 4·4
−3·0	− 7·3	+8·6	− 3·9	.....	+ 2·0	− 0·4	+ 4·0	− 3·8	+ 8·2	.....	+5·2	− 0·2	− 0·5	+ 3·0	− 4·0	+ 2·5	− 3·8	− 4·0

TABLE 4—*Concluded*

K0

M	4071/77	4215/50		4455/62	4247/50	4258/60	4162/68			4455/82	4455/94				4202/07	4489/94	4494/96	4455/89
8·0	.....	− 7·5		+ 7·0	.....	.....	.....			.....	+10·5				.....	.....	.....	.....
6·0	+13·3	− 2·0		+ 1·6	−18·1	−11·7	−13·8			+ 9·0	+ 7·4				.....	.....	.....	.....
4·0	+10·0	+ 1·2		− 1·9	−15·3	− 9·5	−10·5			+ 6·9	+ 4·3				.....	−12·0	+11·2	+12·7
2·0	+ 6·7	+ 4·0		− 4·2	−12·4	− 7·4	− 8·3			+ 4·4	+ 1·3				+ 9·7	− 9·5	+ 7·5	+ 8·8
0·0	+ 3·5	+ 6·5		− 6·2	− 9·4	− 5·1	− 6·0			+ 2·2	0·0				+ 5·8	− 6·6	+ 4·2	+ 5·3
−2·0	+ 0·3	?		.....	− 6·6	− 1·6	− 3·3			− 0·1	+ 2·0				+ 1·0	− 2·0	− 0·5	+ 1·6
−4·0	− 2·8	.....		.....	− 3·6	+ 1·0	− 0·5			− 2·7	+ 4·3				− 5·0	+ 7·5	− 5·2	− 4·8

K5

M	4071/77	4215/50	4455/62	4455/94	4258/60	4202/07	4455/82	4455/89	4489/94	4494/96
8·0	.....	− 5·7	+ 7·2	+ 9·2	.....	.....	+ 8·3	.....	− 1·5	+ 3·0
6·0	.....	− 1·4	+ 1·0	+ 6·2	.....	.....	+ 6·4	+13·0	− 9·0	+11·0
4·0	+10·8	+ 1·3	− 2·5	+ 3·0	.....	.....	+ 4·6	+ 9·7	?	?
2·0	+ 7·0	+ 3·0	− 4·8	0·0	−10·0	.....	+ 2·7	+ 6·5	− 9·5	+ 7·4
0·0	+ 3·4	+ 4·7	− 7·0:	− 2·0	− 6·5	+ 5·0	+ 0·8	+ 3·5	− 6·6	+ 4·0
−2·0	− 0·2	?	?	+ 0·7:	− 2·2	+ 0·7	− 1·3	0·0	− 1·0	− 0·8
−4·0	− 4·2	?	.....	.....	+ 2·0	− 6·0	− 3·6	− 5·0	− 7·5	− 5·9

M0

M	4071/77			4482/94	4258/60	4202/07	4455/82	4455/89	4489/94	4494/96
2·0	+ 7·6			− 3·2	−10·6	+ 7·2	+ 1·6	+ 5·6	− 6·5	+ 4·3
0·0	+ 3·2			0·0	− 6·4	+ 3·2	− 0·7	+ 2·2	− 3·0	+ 0·7
−2·0	− 1·4			+ 3·5	− 2·0	− 0·8	− 2·9	− 1·8	+ 1·8	− 4·0
−4·0	− 5·8			+ 6·7	+ 3·0	− 5·0	− 5·3	− 6·0	+ 7·3	− 8·0

M5

M	4071/77			4482/94	4258/60	4202/07	4455/82	4455/89	4489/94	4494/96
2·0	+10·0			− 6·0	.....	+ 5·0	+ 1·5	+ 5·6	− 1·8	+ 1·3
0·0	+ 3·0			0·0	− 6·6	0·0	− 0·8	+ 2·1	+ 1·8	− 2·8
−2·0	− 3·7			+ 6·0	− 2·0	− 4·6	− 3·0	− 1·8	+ 7·5	− 7·2
−4·0	−10·0			+11·5	+ 2·6	−10·0	− 5·4	− 6·0	+11·5	−12·0

The preceding table gives Young's reduction curves for obtaining the absolute magnitude from the measured intensity of the ratios. The arguments are absolute magnitudes and the body of the table consists of the measured step values.

TABLE 5

F0 F5

M	4071/77	4215/50	4271/90			4247/50	4258/60	4162/68	4071/77	4215/50	4271/90		4247/50	4258/60	4162/68	
7·0	.....	−1·0	.....			.....	−6·4	.....	+5·6	−1·1	+5·1		.....	−6·4	.....	
5·0	+2·7	+0·1	+1·8			.....	−5·1	−4·8	+2·7	+0·2	+2·7		−3·4	−4·8	−4·4	
3·0	−0·7	+1·4	−0·7			−2·4	−3·9	−2·0	− 0·2	+1·5	0·0		−1·8	−3·4	−1·4	
1·0	−3·2	+2·8	−2·8			+1·5	−1·8	+0·4	−2·5	+3·1	−1·5		−0·6	−2·1	+0·2	
−1·0	−5·1	+4·5	−4·6			.....	−0·2	.....	−4·3	+3·7	−4·5		+0·8	−0·9	+2·1	
−3·0	.....	.....	.....			.....	.....	.....	−5·9	+2·7	.....		+2·4	+0·4	+4·4	

G0 G5

M	4071/77	4215/50	4271/90	4455/62	4455/94	4247/50	4258/60	4162/68	4071/77	4215/50	4455/62	4455/94	4247/50	4258/60	4162/68	4202/07	4494/96
7·0	+6·8	−1·6	.....	+2·1	+4·6	−5·2	−6·4	.....	+7·6	−2·2	+2·3	+5·6	.....	−6·2	.....	+1·8	.....
5·0	+3·2	+0·1	+3·5	+0·8	+3·1	−4·5	−5·0	−3·6	+4·0	0·0	+0·7	+3·5	−5·1	−5·1	.....	+3·3	.....
3·0	+1·4	+1·7	+2·3	−0·4	+1·8	−2·6	−3·7	−2·6	+2·7	+2·0	−0·7	+1·9	−3·4	−4·0	−3·9:	.....	+3·8
1·0	−0·4	+3·5	+0·9	−1·6	+0·7	−1·5	−2·6	−1·3	+1·4	+4·2	−2·0:	+0·8	−2·1	−3·0	−3·1	+3·5	+1·8
−1·0	−2·2	.....	−0·8	−1·6	+1·1	−0·5	−1·5	+0·2	+0·1	.....	.....	+1·2	−0·7	−1·9	−1·7	+2·1	0·0
−3·0	−4·2	+3·9	−3·0	−0·2	+2·4:	+0·5	−0·5	+2·2	−2·5	+4·0:	−1·0		+0·5	−0·7	+0·4	+1·1	.....

K0

M	4071/77	4215/50		4455/62	4455/94	4247/50	4258/60	4162/68			4455/82	4455/89	4482/94	4489/94		4202/07	4494/96
8·0	+8·0	−3·2		+4·2	+6·4	−8·4	−6·8:	.....			.....	+5·8	.....	.....		.....	.....
6·0	+6·0	−1·3		+1·4	+3·8	−6·6	−5·6	−4·9			+3·5	+4·2	+0·9	−1·3		+4·0	+2·0
4·0	+4·4	+0·8		−0·4	+2·0	−5·3	−4·6	−5·4			+2·1	+2·7	.....	.....		+6·0	+2·9
2·0	+3·0	+3·3		−1·8	+0·8	−4·2	−3·6	−4·0			+1·2	+1·4	−2·2:	−1·8		+4·0	+1·7
0·0	+1·7	.....		−3·2	.....	−3·1	−2·6	−2·7			+0·5	+0·4	−1·1	−0·7		+2·4	+0·7
−2·0	−0·4	+3·5		−3·7	+1·0	−2·0	−1·5	−1·4			−0·3	−0·7	0·0	+0·5		+0·8	−0·4
−4·0	−1·3	+2·4		−2·5	+2·4	−0·6	−0·2	+0·2			−0·9	−1·8	+1·1	+2·3		−0·8	−1·5

TABLE 5—*Concluded*

K5

M	4071 77	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
8·0	+7·5	+4·6	+6·2	−7·2	−8·4	−1·2	+1·7	+4·4	+6·2	+2·3	+0·1	+0·4
6·0	+6·0	+1·2	+3·8	.....	−7·4	−4·4	+4·5	+2·8	+4·5	0·0	−2·0	+2·9
4·0	+4·8	−1·2	+1·9	.....	−6·4	.....	+5·9	+1·8	+2·9	.....	.....	+3·7
2·0	+3·4	−3·1	+0·6	−7·7	−5·3	−4·0	+4·0	+1·0	+2·2	−1·5	−1·8	+2·3
0·0	+1·6	−3·1	−0·5	−5·4	−3·4	−2·1	+2·2	+0·4	+0·2	−0·4	−0·7	+0·7
−2·0	−0·2	−2·0	−0·2	−3·3	−1·3	+0·4	+0·2	−0·2	−1·0	+0·6	+0·8	−0·7
−4·0	−2·0	.....	+1·7	−1·4	+0·4	.....	.....	.....	−2·0	+1·7	+2·9	−1·6

M0

M	4071 77	4455 62	4455 94	4247 50	4258 60		4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
4·0	.....	.....	.....	.....	−8·0		.....	.....	.....	.....	.....	.....
2·0	+3·6	−0·2	+1·8	.....	−5·5		+3·6	+1·6	+3·3	.....	−2·2	+2·3
0·0	+1·9	−1·7	0·0	−6·0	−4·1		+1·2	0·0	+1·8	+0·2	−0·6	+0·4
−2·0	−0·2	.....	+1·1	−3·9	−1·5		−0·9	−1·0	+0·2	+1·8	+1·3	−1·8
−4·0	−2·0	.....	+1·9	−2·3	+1·0		−3·0	−2·0	−2·9	+3·4	+3·4	−3·2

M5

M	4071 77		4455 94	4247 50	4258 60		4202 07	4455 82	4455 89	4482 94	4489 94	4494 96
2·0	+3·5		.....	.....	−6·7		+3·4	.....	+1·8	.....	−1·7	+1·9
0·0	+1·6		0·0	−6·0	−4·4		+1·2	+1·2	−0·1	+0·8	0·0	−0·8
−2·0	−0·6		+1·6	−4·2	−1·2		−0·8	−0·5	−1·5	+2·6	+2·0	−3·2
−4·0	−2·9		+2·8	−2·6	+1·2		−2·9	−2·4	−3·0	+4·4	+4·4	.....

The table immediately preceding gives Harper's reduction curves for obtaining the absolute magnitude from the measured intensity of the ratios. The arguments are absolute magnitudes and the body of the table consists of measured step values.

The preceding discussion relates to stars of type earlier than K6. In the later K- and M-types the difficulties are more numerous because in the first place we have practically no reliable parallaxes and secondly for about half our stars no spectroscopic parallaxes. This latter, however, did not so much matter as our experience in the late K-type stars led us to believe that the absolute maguitudes published by Mount Wilson for types later than K2 were somewhat unreliable. In any case we desired to have our results as independent as possible. The distinctions between dwarf and giant M stars did not concern us particularly because these are very apparent and only a few dwarf M stars were on our list. We desired reliable criteria for grading the giant M stars.

There were a few stars such as α Orionis, α Scorpii and α Herculis that we felt reasonably sure were real giants both on account of their measured parallaxes and because their proper motion indicated great distances. They showed all the lines on which we placed dependence in the K-type, indicative of a very giant character.

We computed the parallax to be expected for each star according to the formula

$$\bar{\pi} = \bar{\mu}\,(\cdot 089 V_o^2 + 17\cdot 82 \sin^2 d)^{-\frac{1}{2}}$$

The absolute magnitudes derived from this formula were plotted against the step differences measured for the lines which held good in the K-type and which gave every indication of continuing to be of service in later types. It was quite to be expected that these plots would be very discordant on account of the great uncertainties in the assigned magnitudes but nevertheless they did seem to be in accord with a continuation of the lines used in the K-types. Naturally the slope of the curves was somewhat uncertain and we adopted as preliminary practically the same slope as existed in the earlier types and drew the curve so that the absolute magnitudes were represented in the mean. We read off preliminary absolute magnitudes from these curves. It was very satisfactory to find that the accordance between the lines was good. We went through several approximations, first obtaining a set of absolute magnitudes and then replotting curves, trying varying degrees of slope so as to produce on the one hand as good accordance as possible and still have a set of curves which joined on to and was in agreement with the curves already obtained for the K-type.

VII—The Division of the Stars Into Groups and the Determination of the Mean Absolute Magnitudes of the Stars in the Groups

There are several ways of deriving the mean absolute magnitude of a group of stars. The various methods necessarily make use of either the trigonometric parallax or the proper motion. None of the methods are entirely satisfactory because the errors, both accidental and systematic, which are inherent in the observations together with the hypothesis of random motion which must be made, introduce errors which are difficult to evaluate.

Suppose we have a group of N stars for all of which we have radial velocities, proper motions and trigonometric parallaxes. Let

π_c = The ratio of circumference to diameter.
π = The true parallax.
π_o = The measured trigonometric parallax.
$\epsilon_o = \pi - \pi_o$
M_π = The true absolute magnitude, defined as the apparent magnitude at a distance corresponding to a parallax $0''\cdot 1$, so that $M_\pi = m + 5 + 5 \log \pi$.
m = The apparent visual magnitude on the Harvard system.
π_M = The parallax of a star computed from an absolute magnitude.
$M\pi_0$ = The absolute magnitude computed from a measured parallax.
V_0 = The radial velocity of a star corrected for solar motion.

Trigonometric Parallaxes (First Method)

Suppose the N stars have the same M and π and therefore the same m. The observed values of π, if there are no systematic errors, will cluster about π some being less and some greater. Let the observed distribution of the errors follow the law of propagation of error with a probable error ρ. The number of errors lying between x and $x + dx$ is given by

$$N \frac{h}{\sqrt{\pi_c}} e^{-h^2x^2} dx$$

where $h = \cdot 4739\ \rho^{-1}$.

For these stars, the observed π_0 is $\pi + x$ and

$$M\pi_0 = 5 + m + 5 \log (\pi + x).$$

Hence the average observed absolute magnitude will be given by

$$\frac{1}{N} \int_{-\infty}^{+\infty} N(5 + m + 5 \log \overline{\pi + x}) e^{-h^2x^2} \frac{h}{\sqrt{\pi_c}} dx.$$

This reduces to

$$5 + m + 5 \log \pi + \frac{5h}{\sqrt{\pi_c}} \int_{-\infty}^{+\infty} \log \left(1 + \frac{x}{\pi}\right) e^{-h^2x^2} dx.$$

The correction to the computed value of M is

$$- \frac{5h}{\sqrt{\pi_c}} \int_{-\infty}^{+\infty} \log \left(1 + \frac{x}{\pi}\right) e^{-h^2x^2} dx,$$

or

$$- \frac{5h}{\sqrt{\pi_c}} \int_{o}^{\infty} \frac{\log \left(1 + \frac{x}{\pi}\right) + \log \left(1 - \frac{x}{\pi}\right)}{10^{(h^2x^2).4343}} dx.$$

This integral, if extended to the limits given, is a complex quantity due to the fact that the logarithm of a negative quantity is imaginary but in the evaluation of the mean absolute magnitudes from individual trigonometric parallaxes negative values can not be used. If the integral is extended over the limits for which the computed absolute magnitudes are real the integral is always positive showing that the absolute magnitudes derived in this way will be too small or that the stars will be computed more giantish than they really are. The difficulty of having negative values in connection with trigonometric parallaxes is one that can not be overcome and the theoretical treatment must at best be an approximation. In the treatment of this question in the work of the Mount Wilson Observatory the error function is expanded in a series. Thus on page 4 of Contribution No. 199 they put

$$\tau = 1 + E + \tfrac{1}{2} E^2$$

but this series is only legitimate provided E is less than unity. Theoretically E extends from plus infinity to minus infinity but in practice it will be small and the formula serves to show the nature of the operation of the laws of error on the derived absolute magnitude.

To obtain the numerical value of the integral we may plot the curves

$$y = \frac{5h}{\sqrt{\pi_c}} \frac{\log \left(1 + \frac{x}{\pi}\right) + \log \left(1 - \frac{x}{\pi}\right)}{10^{(h^2x^2).4343}}$$

for various values of h and π. (cf. Figure 9).

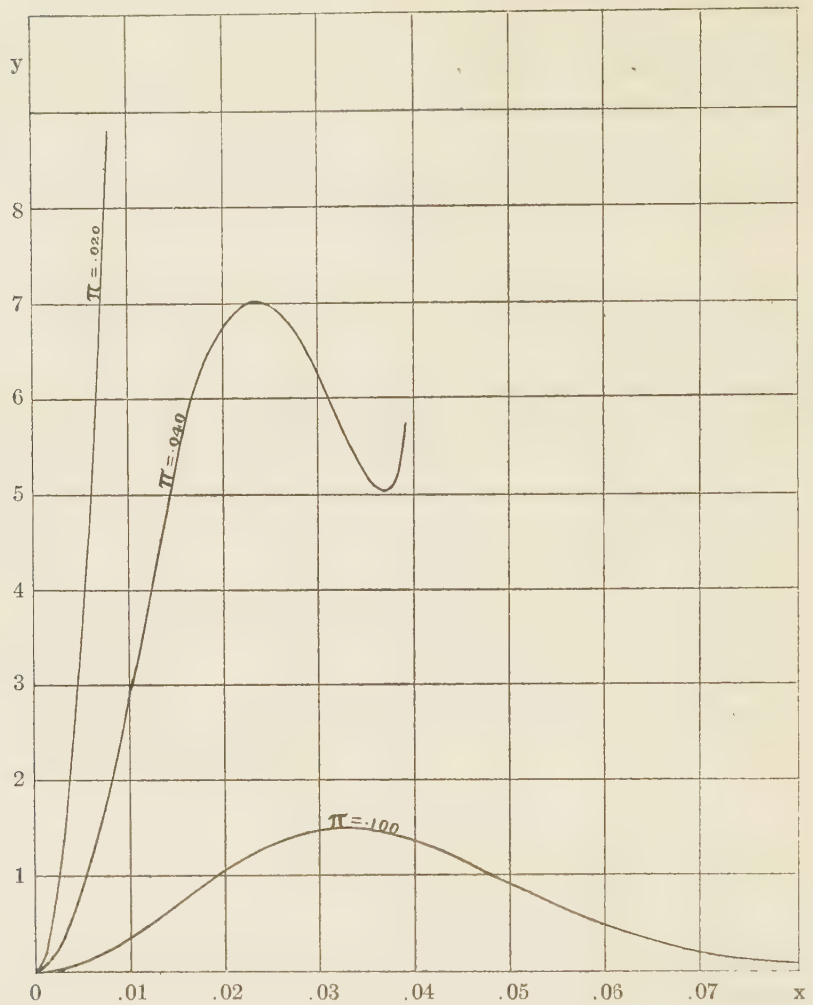


FIG. 9. The Function $y = \frac{5h}{\sqrt{\pi}} \cdot \frac{log\,(1 + x/\pi) + log\,(1 - x/\pi)}{10^{h^2x^2 \cdot 434_3}}$

Each curve is asymptotic to a line whose abscissae is equal to the parallax of the group for which the curve is drawn. For the curve with the smallest ordinate at maximum, for which $\pi = \cdot''100$ and $\rho = \cdot 015$ nearly all the errors are less than the parallax for the group and the correction which must be applied can be measured from the area to be about $\cdot 06$ of a magnitude if we neglect errors greater than $\cdot''093$ in π. In practice errors half this size very seldom occur. It must not be forgotten, however, that among measured parallaxes positive errors are more likely to be present than negative ones. The extent to which this tendency is present in a group is quite unknown but it probably has a much larger effect than the one just calculated and it will operate in the opposite way.

The second curve for which $\pi = \cdot''040$ has been computed on a basis of a probable error in the parallaxes $\cdot''010$. The correction to M is less than $0 \cdot 2$ if we neglect errors greater than $\cdot''036$. A considerable percentage of the errors would be greater than $\cdot''036$ were they distributed according to the laws of error. It seemed to us that in both these groups of stars the neglected negative errors would more than counterbalance

our computed corrections and we have accepted the absolute magnitude computed for the groups by this method without alteration. The foregoing considerations have been derived for a group of stars all of the same m and π but they hold equally true for a group of stars where this condition is not demanded.

Trigonometric Parallaxes (Second Method)

Instead of computing the absolute magnitude corresponding to each star, we may take the mean of the observed parallaxes first and then derive

$$\overline{M\pi_0} = \overline{m} + 5 + 5 \log \overline{\pi_0}$$

where the bar indicates mean values. This method has the advantage of being able to include negative parallaxes and the only correction to the computed absolute magnitude will be

$$5 \overline{\log \pi_0} - 5 \log \overline{\pi_0}$$

For a large group of stars we may assume that the accidental error in the measured parallaxes vanish so that $\overline{\pi} = \overline{\pi_0}$. We would be in a position to calculate the magnitude of the correction if we knew the distribution of the values of the true parallaxes between various limits for the stars in the group.

As an example we will take the 39th group of our list. In this group there are thirteen stars whose approximate M, m and π are given in the following table.

M	m	π_M	M	m	π_M	M	m	π_M
0·9	4·6	·018	0·7	4·4	·018	0·3	5·6	·009
0·8	4·7	·016	0·5	4·5	·016	0·6	5·9	·009
1·1	1·1	·100	0·2	4·1	·016	0·3	4·9	·012
0·7	5·9	·009	0·3	3·0	·029	.....	.....	.....
0·5	4·2	·018	0·5	5·5	·010	.....	.....	.....

We do not know the true parallaxes for these stars but those given are approximate values and assuming that these are sufficient to compute a correction, which usually will be small, we can at once derive

$$5 \overline{\log \pi_M} - 5 \log \overline{\pi_M} = -0{\cdot}60$$

The absolute magnitudes obtained by the second method are too dwarfish. The correction 0·60 arises largely from the introduction of the one star whose apparent magnitude is 1·1. The correction would be reduced to −0·14 if this star were omitted. We see, therefore, that the mean M computed by this method will be very good if we include stars in one group with reasonably small dispersion in M and m. The true mean absolute magnitude of the group should lie between the values found by the first and second methods provided one can neglect the general tendency to measure trigonometric parallaxes too large. Both methods, however, are best applicable to stars of fairly well determined parallax. The proper motions of the stars must be relied upon for the mean parallax of the most distant stars.

Proper Motions

The first method that occurred to us to use was that developed by Kapteyn giving the mean parallax as a function of the apparent magnitude and proper motion. This method has been elaborated by Van Rhijn in Gronigen Publications, Number 34. The objection we see to the method, however, is that the stars are divided into groups on the basis of the proper motions which are themselves to be used for getting the mean parallaxes. Moreover, when we select a list of small proper motion stars we may pick out those that are moving most rapidly in the line of sight. That these tendencies are operative is shown from Van Rhijn's work itself when he finds that the mean parallax of stars of zero proper motion is not zero. It seemed to us inevitable that the method would make the giant stars too giantish. The objection we have urged against taking the proper motions as a basis of division holds, though possibly with diminished force, when the grouping is based on a particular component of the proper motion.

We have used the two well known formulae

$$\pi = 0{\cdot}237 \frac{\upsilon \sin \lambda}{\sin^2 \lambda}$$

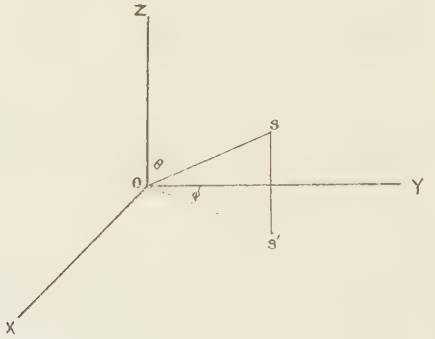
$$\pi = 4{\cdot}738 \frac{\tau}{V_0}$$

and a third formula

$$\pi = \mu \, (17{\cdot}8 \sin^2 \lambda + {\cdot}089 \, V_0^2)^{-\frac{1}{2}}$$

which we will now develop.

Suppose we have N stars at the point α and δ in the sky whose distance from the apex of the sun's way is λ. Suppose also that all these stars are at the same distance, parallax π, and further let the space velocity of all the stars be the same, V_s. Suppose the stars in regard to direction of motion are moving at random, then the N vectors representing the space velocities of the stars will have their ends uniformly distributed over a sphere.



At the point O draw three rectangular axes, OZ in the direction of the line of sight, OY in the direction of antiapex and OX, perpendicular to these two. The proper motion component caused by the velocity of the sun through space lies along the line OY. Let K represent it.

$$K = {\cdot}2111 \, V\odot\pi \sin \lambda$$

K is expressed in seconds of arc per year if $V\odot$, which is the velocity of the sun is in kilometres per second. Let OS represent the peculiar velocity of the star. OS′ is the

component which contributes to the observed proper motion. Let

$$L = \cdot 2111\ Vs.\ \pi$$

then the proper motion component due to the space velocity V_s of the star equals $L \sin \theta$. The total observed proper motion is given by

$$\mu^2 = (K^2 + L^2 \sin^2\theta + 2KL \sin \theta \cos \phi)\ \pi^2.$$

For stars for which θ is constant we obtain the average value of μ to be given by

$$\bar{\mu} = \frac{1}{\pi} \int_0^{\pi} (K^2 + L^2 \sin^2\theta + 2KL \sin \theta \cos \phi)^{\frac{1}{2}} d\phi$$

and if we are content to take the mean of the square of μ we obtain

$$\bar{\mu^2} = \frac{1}{\pi^2} (K^2 + L^2 \sin^2\theta).$$

The number of stars which will have a value θ lying between and $\theta + d\theta$ is given by

$$\frac{N}{2} \sin \theta\ d\ \theta$$

and since in our formula for mean values the angle enters as the square we have the total number of stars for which $\sin^2 \theta$ is alike to be N $\sin \theta\ d\ \theta$, The average value of μ^2 for all the stars is given by

$$\bar{\mu^2} = \int_0^{\frac{\pi}{2}} (\mathrm{K}^2 \sin \theta + \mathrm{L}^2 \sin^3\theta)\ d\theta$$

$$= K^2 + \tfrac{2}{3} L^2$$

$$= (\cdot 2111\ V\odot)^2 \sin^2\lambda\pi^2 + \tfrac{2}{3} (\cdot 2111\ V_s)^2\pi^2.$$

Letting $V\odot = 20$ km and putting $V_s^2 = 3\ V_s^2$ we get

$$\bar{\mu^2} = (17 \cdot 8 \sin^2\lambda + \cdot 089\ V_0^2)\ \pi^2$$

We have used this formula in the form

$$\bar{\mu} = (17 \cdot 8 \sin^2 \lambda + \cdot 089\ V_0^2)^{\frac{1}{2}}\ \bar{\pi} \quad (\textit{See footnote})$$

As certain assumptions are made here in regard to mean values it will be of interest to compare results from this formula with those derived from τ and υ. Table 6 shows a comparison for fifty groups of stars. The second column gives the number of stars in the group and the third, fourth and fifth columns give the parallaxes computed by the three methods. The sixth column gives what we would consider the best parallax for the group. In the great majority of groups this is the mean from the three methods. In those that are marked with an * it is the mean parallax based on the trigonometric values. The last three columns contain the ratios of the parallax computed by the various methods to the adopted parallax for the group and at the bottom of these columns are the means and the mean departures from unity. These show that the formula reproduces the correct parallax very closely in the mean and that for individual small groups of stars it gives better results than either the τ or υ formula.

In the formula as we first derived it, we put $Vs = 2V_0$ or $Vs^2 = 4V_0^2$. Dr. Luyten pointed out to us that in the mean $Vs^2 = 3V_0^2$, and we have introduced this correction and used the corrected formula in our comparison of results given in Section VIII. Owing to the fact that we have computed the parallaxes by three methods and taken the mean the effect of the change on the final values is very small, rarely amounting to as much as 0·10 magnitude.

TABLE 6

Group	No. of stars	π_τ	π_v	π_f	π	π_τ/π	π_v/π	π_f/π
1	7	·0074	·0253	·0156	·0161	0·46	1·57	0·97
2	16	·0170	·0214	·0189	·0191	0·89	1·12	0·99
3	17	·0193	·0176	·0216	·0195	0·99	0·90	1·11
4	7	·0510	−·0029	·0260	·0247	2·07	−0·12	1·05
5	10	·0205	·0153	·0158	·0172	1·19	0·89	0·92
6	13	·0101	·0158	·0144	·0134	0·75	1·18	1·07
7	26	·0239	·0260	·0223	·0241	0·99	1·08	0·93
8	35	·0146	·0200	·0207	·0184	0·79	1·09	1·13
9	43	·0287	·0412	·0326	·0342	0·84	1·20	0·95
10	20	·0247	·0184	·0241	·0224	1·10	0·82	1·08
11	10	·0038	·0046	·0047	·0044	0·86	1·04	1·07
12	11	·0324	·0395	·0365	·0361	0·90	1·10	1·01
13	36	·0462	·0442	·0446	·0450	1·03	0·98	0·99
14	29	·0532	·0426	·0468	·0475	1·12	0·90	0·99
15	12	·0017	·0042	·0031	·0030	0·57	1·40	1·03
16	13	·0130	·0030	·0184	·0217	0·60	1·52	0·85
17	15	·0227	·0004	·0168	·0133	1·71	0·03	1·26
18	16	·0514	·0639	·0547	·0567	0·91	1·13	0·97
19	22	·0566	·0893	·0635	·0698	0·81	1·28	0·91
*20	13	·0843	·0869	·0812	·0713	1·18	1·22	1·14
21	4	·0036	·0064	·0056	·0052	0·69	1·23	1·08
22	9	·0155	·0250	·0158	·0188	0·82	1·33	0·84
23	16	·0244	·0473	·0381	·0366	0·67	1·29	1·04
24	58	·0099	·0098	·0103	·0100	0·99	0·98	1·03
25	65	·0161	·0212	·0170	·0181	0·89	1·17	0·94
26	6	·0316	·0678	·0338	·0433	0·73	1·57	0·78
27	12	·0753	·0988	·0669	·0803	0·94	1·23	0·83
*28	13	·1471	·1112	·1449	·1234	1·20	1·04	1·18
29	3	·0098	·0000	·0042	·0047	2·08	0·00	0·89
30	52	·0094	·0136	·0101	·0110	0·85	1·24	0·92
31	49	·0148	·0161	·0166	·0159	0·93	1·01	1·04
32	19	·0373	·0332	·0331	·0345	1·08	0·96	0·96
33	6	·0071	·0118	·0081	·0090	0·79	1·31	0·90
34	14	·0062	·0076	·0061	·0060	0·94	1·15	0·92
35	25	·0071	·0063	·0075	·0069	1·03	0·91	1·09
36	24	·0132	·0147	·0135	·0137	0·96	1·07	0·99
37	12	·0285	·0200	·0281	·0252	1·13	0·79	1·12
*38	3	·1915	·4130	·3171	·1760	.....	.....	.....
39	8	·0092	·0093	·0088	·0091	1·01	1·02	0·97
40	13	·0107	·0139	·0116	·0121	0·88	1·15	0·96
41	16	·0102	·0194	·0116	·0137	0·74	1·41	0·85
*42	4	·2412	·5528	·2845	·2220	.....	.....	.....
43	5	·0046	·0031	·0032	·0036	1·29	0·86	0·89
44	16	·0087	·0047	·0060	·0064	1·36	0·74	0·94
45	23	·0080	·0054	·0074	·0069	1·16	0·78	1·07
46	11	·0091	·0234	·0121	·0149	0·61	1·57	0·81
47	13	·0076	·0067	·0077	·0074	1·03	0·91	1·04
*48	12	·042	·0740	·0476	·0800	0·43	0·93	0·60
49	24	·0060	·0110	·0103	·0090	0·67	1·22	1·15
*50	14	·1418	·1171	·1219	·1180	1·20	0·99	1·03
.....	.....	.....	.....	.....	.....	16·5	18·1	7·5
.....	.....	.....	.....	.....	.....	101·2	108·5	99·5

We think that any of the three formulae will give good results if used for groups of stars which do not favour either large or small proper motions. The first method of division we considered was the trigonometric parallaxes. These are perfectly satisfactory for the nearer stars. In the case of the more distant stars the large accidental errors tend to throw together stars of widely different absolute magnitudes and in addition it tends to form a group of fictitiously giant stars. This difficulty could be almost entirely overcome if we had *two* methods of dividing the stars into groups each of which was independent of the proper motion and also of each other, because the chances that any particular star would be accidentally measured with a small parallax in both systems could be neglected. We have assumed that the spectroscopic parallaxes are sufficient for this purpose and accordingly have used as absolute magnitudes the means of the Mount Wilson spectroscopic and those derived from the trigonometric parallaxes as a basis for dividing the giant stars into groups. The mean parallax for each group was computed by each of the three formulae given above and the mean taken and then the mean absolute magnitude computed by

$$\overline{M} = \overline{m} + 5 + 5 \log \overline{\pi}$$

VIII—The Determination of the Final Absolute Magnitudes and a Comparison of the Results With Those Obtained at Other Observatories and Those Derived From Proper Motions and Parallaxes

When the work described in the preceding sections was completed we made a comparison of our absolute magnitudes with those obtained at other observatories. The results of this work were published in the Journal of the Royal Astronomical Society of Canada for January, 1924. The comparison rested on 500 stars which we used to derive our reduction curves and special attention was given to the later types. The present discussion is based on all available stars. Our final values are given in table 7 at the end of the publication. In a few cases these differ from those published in the Journal of the R.A.S.C. This difference is very small as a rule and arises in some cases from extra plates having been secured and in other cases from slight changes in our reduction curves. We have included quite a large number of A-type stars, some as early as type A2, when the spectra contained sharp lines. The results for these stars should be accepted as very tentative until more accurate reduction curves are available and likewise the very latest type stars, say from M6 to M8, are liable to greater errors than the general average for the curves relating line intensity to absolute magnitude are necessarily most poorly defined at the ends of the sequence of types.

For 920 stars of the 1105 stars given in table 7, which has been placed at the end for convenience, we have both proper motions and radial velocities. These were divided into fifty groups according to type and absolute magnitude as determined here. The number of stars in these groups and their mean types are shown in the first three columns of table 8. The fourth column gives the mean absolute magnitude derived as indicated in section

TABLE 8

Group No.	No. of Stars	Mean Type	Comp M for μ	Corrected M	Corr. from ·013 cos δ	M Young	M. Harper	Stars with Trig π	Mean M	M Young	M Harper	No. of Stars	Mt.W. M	Vict. M
1	7	A5·0	1·13	0·73	0·60	+0·63	0·44	.....	.....	.....	.....	3	2·13	0·47
2	16	A5·8	1·63	1·43	.....	1·67	1·69	.....	.....	.....	.....	7	1·98	1·61
3	17	A5·2	1·59	1·47	.....	2·39	2·29	.....	.....	.....	.....	4	1·88	2·28
4	7	A5·3	2·64	2·47	.....	3·41	2·91	.....	.....	.....	.....	3	2·27	2·87
5	10	F3·0	0·42	0·04	−0·20	−0·90	−0·73	.....	.....	.....	.....	6	−0·97	−1·15
6	13	F3·4	0·58	0·35	.....	+0·49	+0·62	.....	.....	.....	.....	9	0·16	0·48
7	26	F2·1	2·09	1·81	.....	1·50	1·58	.....	.....	.....	.....	9	1·46	1·55
8	35	F2·5	1·95	1·76	.....	2·48	2·33	8	2·62	2·43	2·50	14	2·59	2·50
9	43	F3·7	3·23	3·09	.....	3·39	3·19	23	3·32	3·35	3·19	22	3·10	3·29
10	20	F4·1	2·71	2·48	.....	4·15	3·78	8	4·27	3·99	3·90	8	3·50	3·99
11	10	F7·5	−2·66	−2·87	−3·71	−2·15	−2·16	.....	.....	.....	.....	7	−2·07	−2·27
12	11	F7·1	2·86	2·36	+2·24	+1·51	+1·60	.....	.....	.....	.....	7	1·47	1·33
13	36	F7·1	3·89	3·43	.....	3·62	3·42	24	4·00	3·63	3·50	24	3·55	3·58
14	29	F7·8	3·96	3·76	.....	4·33	4·11	22	4·10	4·30	4·18	21	3·87	4·23
15	12	F7·9	4·18	3·97	.....	5·08	4·82	11	5·21	5·13	4·85	11	4·36	5·01
16	12	G1·5	−2·70	−3·19	−3·55	−2·62	−2·27	.....	.....	.....	.....	11	−3·04	−2·70
17	13	G3·7	1·97	1·47	.....	+0·65	+0·59	.....	.....	.....	.....	7	0·07	0·71
18	15	G2·3	0·18	−0·27	.....	1·85	1·63	.....	.....	.....	.....	9	0·57	1·62
19	16	G1·9	4·03	3·65	.....	3·46	3·37	10	3·44	3·40	3·34	12	3·31	3·29
20	22	G1·2	4·66	4·50	.....	4·49	4·29	19	4·67	4·54	4·32	20	4·47	4·43
21	13	G1·2	5·69	5·61	.....	5·09	4·70	12	5·18	5·10	4·73	11	4·97	4·93
22	4	G6·5	−1·75	−1·93	−3·06	−2·55	−2·35	.....	.....	.....	.....	2	−2·35	−2·85
23	9	G6·3	0·78	0·45	+0·19	−0·49	−0·42	.....	.....	.....	.....	5	−0·92	−0·36
24	58	G6·8	0·36	0·12	.....	+0·49	+0·54	.....	.....	.....	.....	25	0·08	0·56
25	65	G7·2	1·28	1·06	.....	1·09	1·30	.....	.....	.....	.....	44	0·90	1·40
26	16	G7·2	2·58	2·10	.....	2·34	2·18	.....	.....	.....	.....	11	1·85	2·25
27	6	G6·5	4·08	3·68	.....	3·58	3·33	4	4·21	3·48	3·48	4	3·78	3·60
28	12	G6·8	5·08	4·88	.....	4·58	4·50	10	4·31	4·56	4·54	11	4·69	4·52
29	13	G7·0	6·33	6·13	.....	5·73	5·59	13	5·95	5·73	5·58	13	5·65	5·66
30	3	K2·2	−1·45	−1·60	−2·75	−3·57	−3·38	.....	.....	.....	.....	2	−3·20	−3·80
31	23	K1·6	0·00	−0·45	−0·70	−0·75	−0·72	.....	.....	.....	.....	10	0·32	−0·76
32	52	K0·9	0·72	+0·38	.....	+0·41	0·50	.....	.....	.....	.....	20	1·34	0·59
33	49	K0·7	1·05	+0·84	.....	1·33	1·29	.....	.....	.....	.....	26	0·87	1·32
34	19	K0·6	2·91	+2·68	.....	2·49	2·34	12	2·04	2·62	2·53	12	2·40	2·58
35	14	K0·7	6·31	+5·99	.....	5·66	5·63	14	6·00	5·66	5·63	12	5·80	5·63
36	6	K3·5	−0·40	−0·66	−0·72	−2·05	−1·73	.....	.....	.....	.....	4	−0·30	−1·78
37	14	K4·1	−0·72	−1·28	−1·74	−1·00	−1·00	.....	.....	.....	.....	6	0·35	−0·68
38	25	K4·1	−0·63	−0·95	−1·41	−0·30	−0·28	.....	.....	.....	.....	10	0·48	−0·33
39	24	K3·6	0·68	0·41	.....	+0·41	0·40	6	0·97	0·15	0·46	10	0·55	0·42
40	12	K3·2	1·29	1·04	.....	1·79	1·58	9	0·84	1·42	1·66	11	0·55	1·82
41	3	K4·3	8·24	8·24	.....	6·82	7·03	3	7·04	6·82	7·00	3	6·97	6·93
42	8	K7·1	0·25	0·09	−0·32	−1·08	−0·91	.....	.....	.....	.....	1	0·70	−1·00
43	13	K7·5	0·39	0·23	−0·06	−0·19	0·02	.....	.....	.....	.....	8	0·46	−0·12
44	16	K7·3	0·36	0·00	.....	+0·39	0·47	.....	.....	.....	.....	12	0·52	0·48
45	5	K7·0	9·19	9·08	.....	7·78	7·86	5	7·49	7·78	7·66	5	8·02	7·82
46	5	M2·6	−4·03	−4·63	−5·55	−3·76	−3·42	.....	.....	.....	.....	4	−1·75	−3·68
47	16	M2·4	−0·67	−0·89	−1·42	−1·43	−1·27	.....	.....	.....	.....	10	0·22	−1·36
48	23	M1·8	−0·59	−0·77	−1·10	−0·53	−0·65	.....	.....	.....	....	17	0·17	−0·56
49	11	M1·1	+0·66	0·43	+0·25	+0·23	−0·18	.....	.....	.....	.....	8	0·28	−0·62
50	13	M6·2	−0·56	−0·72	−1·56	−1·51	−1·81	.....	.....	.....	.....	9	−0·60	−1·73

A comparison of the computed and observed mean absolute magnitudes for the various groups.

VII. The proper motion of each star was first reduced to what it would have been had its apparent magnitude been the mean of the group. This procedure tends to reduce the weight given the brighter stars which is too great if the proper motions are used as observed. The fifth column gives a corrected value when the correction

$$5 \log \pi_M - 5 \log \overline{\pi_M}$$

was applied. We assumed that our spectroscopic parallaxes were sufficiently accurate to compute this correction. An inspection of columns four and five shows that it rarely exceeded two or hree tenths of a magnitude.

Kapteyn suggested that the proper motions of Boss' Preliminary General Catalogue may need a correction to the declinations of the form

$$\Delta \delta = + \cdot 013 \cos \delta$$

and while the magnitude of this correction at least has been contested, it seemed to us worth while to investigate how much its introduction would alter our computed values. Accordingly we performed the necessary labour for several of the groups which contained stars of small proper motion. The results are shown in column six. The introduction of the correction tends to make the computed absolute magnitudes more giantish as a rule and the new values are sometimes in better agreement with our derived absolute magnitudes than the old. This is notably the case in group 30 but the group contains only three stars and should not be given much weight. Other groups such as 11 and 16 are made considerably worse but even leaving out of consideration this correction, our magnitudes seem to be somewhat too faint for the very giant stars and as a further test we have formed one group of all the types earlier than M0. For 29 stars which are called c-stars our mean absolute magnitude is $-2 \cdot 60$. The Mount Wilson absolute magnitude for the same stars is $-2 \cdot 56$, in substantial agreement but we compute the mean magnitude should be about $-3 \cdot 1$. Van Rhijn contends in Groningen Publication No. 34 that the Mount Wilson values for these stars are too faint, though he makes the correction larger than is indicated by these figures. The seventh and eighth columns give our own absolute magnitudes. In order to get a general picture of the agreement between the computed and observed values we have plotted them in figure 10. There does not seem to be much systematic difference.

80600—3½

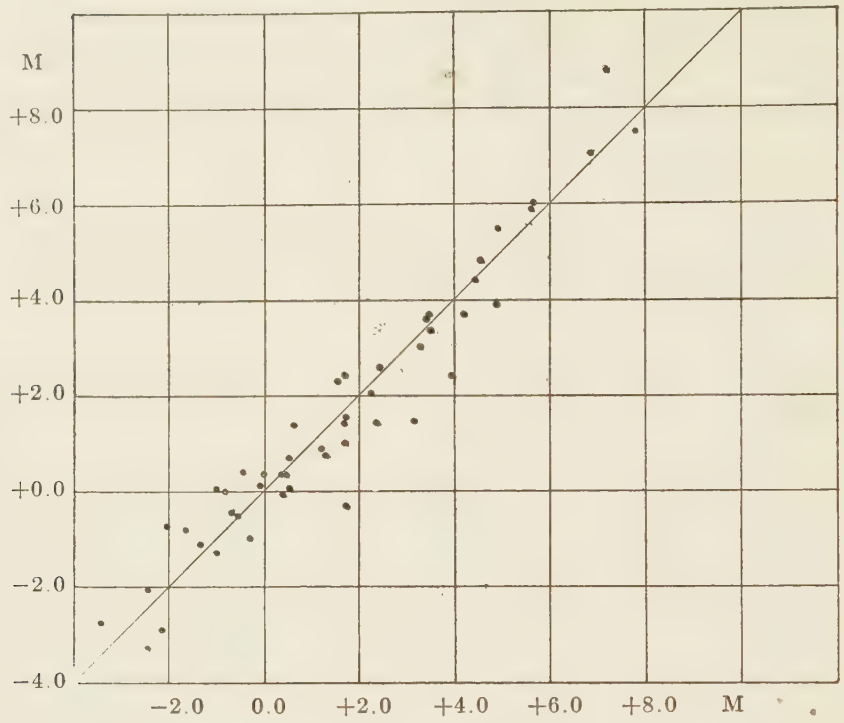


FIGURE 10.

Graph showing the relation between the computed and observed absolute magnitudes for various groups. The abscissae are Victoria values and the ordinates are computed.

We made a comparison with the trigonometric parallaxes also wherever we thought the latter were sufficiently accurate. Columns 9, 10, 11 show this comparison. The number of stars with good parallaxes were so few in very many of the groups that they formed a very poor basis for comparison and for these groups no data are entered. For the groups where there is any considerable number of observed parallaxes the agreement is good. The last three columns give a comparison with the Mount Wilson results. An inspection of the English results on the absolute magnitudes of five hundred stars published in the Memoirs of the Royal Astronomical Society, Volume 72, shows that they are in very close agreement with the Mount Wilson values and so we have not made a detailed comparison of their results for the same groups of stars. In the mean, however, it would seem that the three systems are in substantial agreement.

Group means as shown in table 8 are very good for arriving at systematic differences but they give no idea of the accidental departures for individual stars. These are better shown in figures 11, 12, 13, 14 and 15 where we have plotted the results for each star separately.

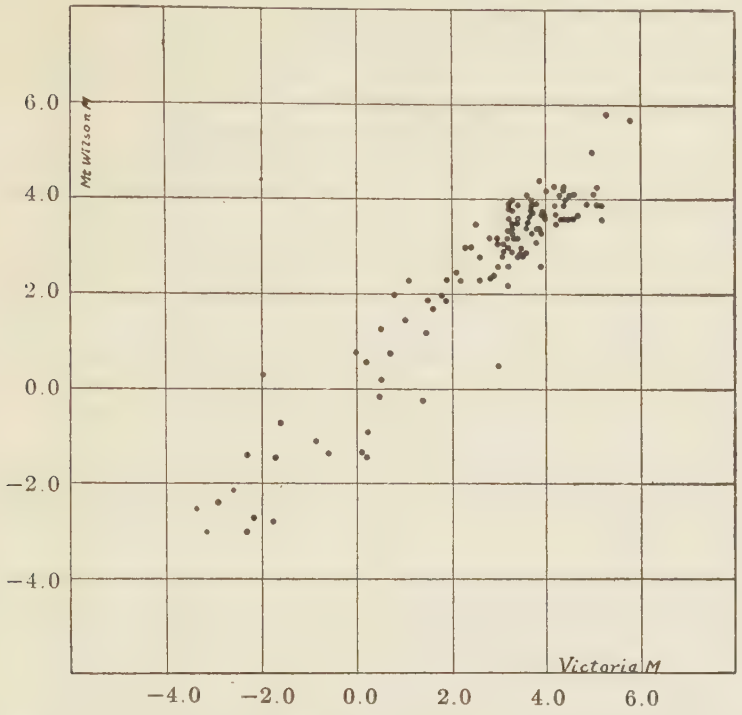


FIG. 11. Comparison of Victoria and Mount Wilson Absolute Magnitudes in Types F0-F9. Ordinates are Mount Wilson Values, Abscissae are Victoria Values

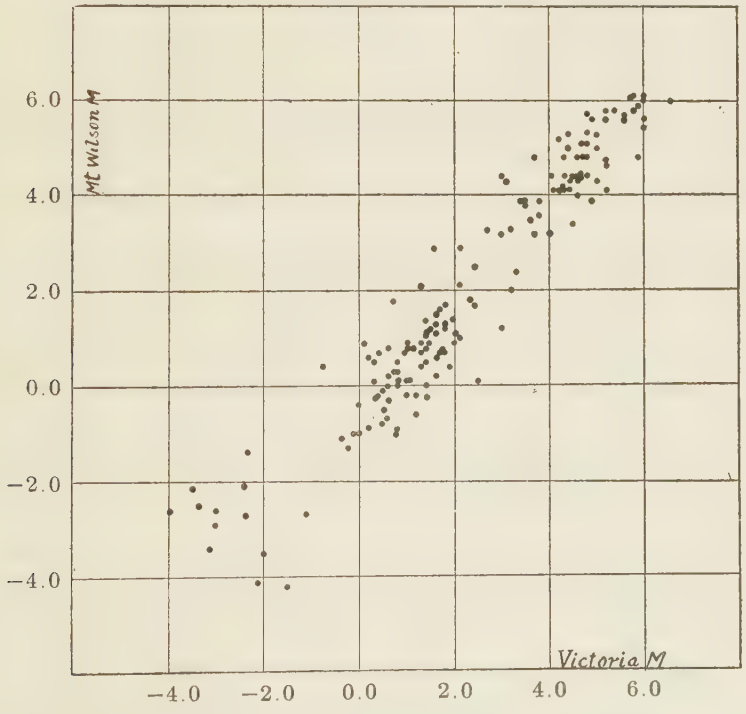


FIG. 12. Comparison of Victoria and Mount Wilson Absolute Magnitudes in Types G0-G9

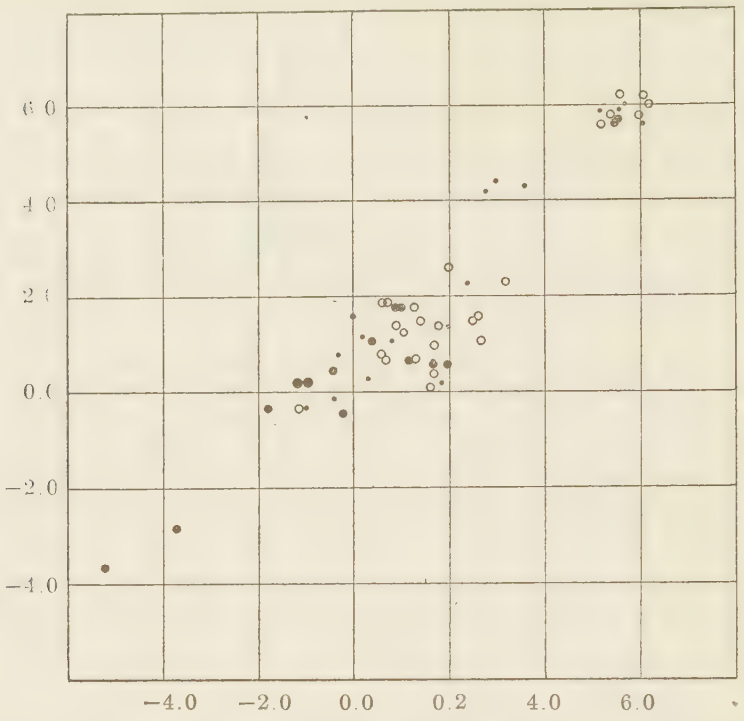


FIG. 13. Comparison of Victoria (abscissae) and Mount Wilson (ordinates) values for Types K0, 1, 2. Small dots are K0, open circles are K1 and filled circles K2

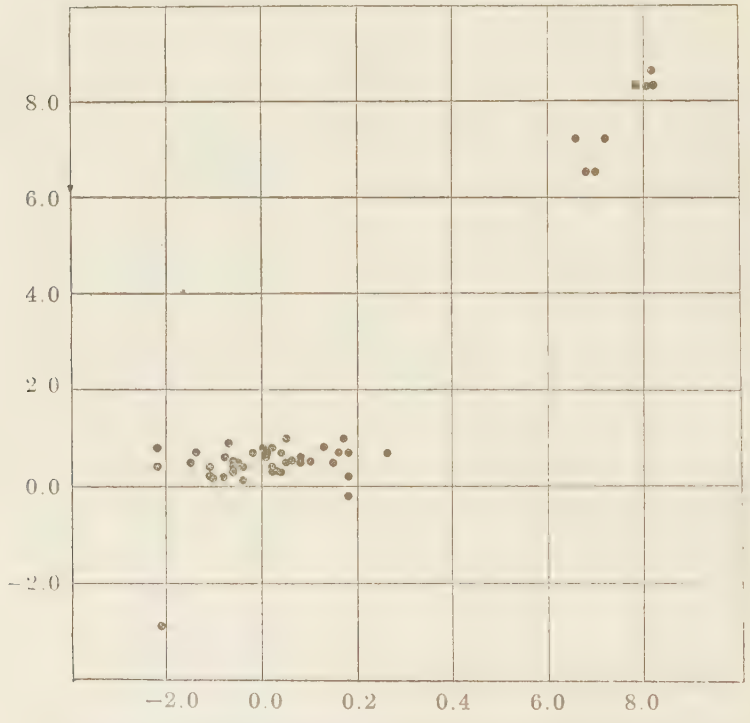


FIG. 14. Comparison of Victoria (abscissae) and Mount Wilson (ordinates) Absolute Magnitudes in Types K3-K9

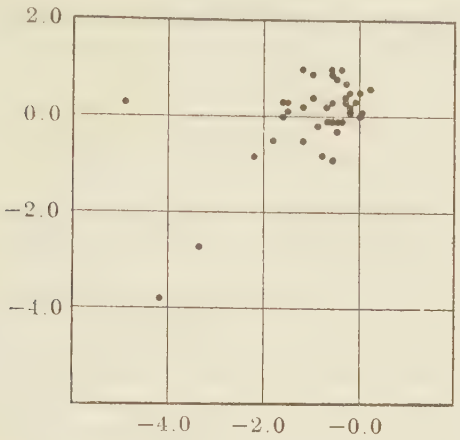


FIG. 15. Comparison of Victoria and Mount Wilson Absolute Magnitudes for M Types. Ordinates are Mount Wilson Values; abscissae are Victoria Values. The very discordant star is μ Cephei

The points in these diagrams would lie along lines inclined at an angle of forty-five degrees and passing through the points O, O if all our values were in perfect agreement with theirs. Departures of the plotted points from these lines show the discordances for individual stars. The agreement in the dwarfs is better than that in the giants as a rule. Those stars which are brighter than absolute magnitude minus two are listed almost without exception by the Mount Wilson Observatory as *c*-stars. While the agreement between our values and theirs is not quite so good here as in the dwarfs, the fact that they join on with our other values seems to justify the contention that they form a part of the regular stellar sequence. In the stars of type G5-K2 from absolute magnitude about 0 to +2 our values seem to be nearly one magnitude fainter and a re-examination of the groups in table 8, numbers 24, 25, 32 and 33, which contain large numbers of stars indicates that our values are a little too positive though by no means one magnitude.

Additional evidence on this point is available from those stars that belong to the Taurus cluster. Thirteen stars in table 7 are members of the cluster and the Victoria mean parallax for these is $0''\cdot0238$ as compared with the corresponding value of $0\cdot0255$ from the proper motion. There are 8 stars from A4 to F4 inclusive the mean value of whose parallax is $0''\cdot018$ and 5 stars from G2 to K1 inclusive whose mean value is $0''\cdot033$. For the latter group a correction of three or four tenths of a magnitude would bring their mean parallax into line and such correction might be justified. We have, however, allowed the values given in table 7 to stand until such time as a more detailed investigation of systematic errors in the results, one embracing the residuals from each line, can be made.

The greatest divergence in the results from the two observatories is shown in the giant stars of types K3 to K9. We obtain a dispersion of four or five absolute magnitudes for this class while they get a very much smaller range. This point was investigated quite fully in our former publication. The K-type stars were divided into eight groups and the M-type stars into four groups and the absolute magnitude computed by proper motion methods. The basis of division in these groups was our own absolute magnitudes, i.e., lines parallel to the ordinates in figure 14. This seems to be the logical method

for testing the reality of the dispersion. Table 9 gives the results of the computation and the range in the absolute magnitudes which we obtain seem to be real.

TABLE 9

No. Stars	Type	M from μ	M Young	M Harper	M Mt. Wilson
3	K2	−2·68	−3·87	−3·33	−2·28
5	K1	−1·32	−1·02	−0·72	−0·06
7	K1	−0·06	+0·03	−0·04	+0·73
16	K1	+1·41	+1·64	+1·52	+1·01
9	K1	+1·02	+0·99	+0·88	+1·27
8	K1	+3·39	+3·08	+2·81	+2·68
8	K4	−2·54	−1·74	−1·20	0·0
9	K4	−1·60	−0·51	−0·02	0·5
9	K4	+0·58	+1·55	+1·39	0·5
10	K7	+0·22	+0·40	+0·40	0·5
7	M2	−3·10	−3·25	−2·90	−1·5
24	M2	−0·75	0·55	−1·20	0·2
12	M2	−0·30	−1·42	−0·64	0·2
11	M1	+0·21	+0·25	−0·24	0·3

All the stars of types K6 to K9 have been included in one group. In our completed list of stars we have a considerable number of additional stars of this class not given in the Mount Wilson list and in table 8 we divided them into 4 groups. In the case of the giants the dispersion in absolute magnitude as shown by the proper motions does not seem to be nearly as large as we get it. Our spectra for very many of these stars are weak and our accidental error is proportionately quite large. It seems to us that the range in absolute magnitudes must exist here, however, as it is definitely shown in the stars of types K3 to K5 and also in the M-types and our reduction curves are continuous over the gap.

Accidental Errors

The determination of the size of the accidental error which affects the results for absolute magnitude is a difficult problem to solve. The reason is that there are very few stars for which we have trustworthy individual absolute magnitudes other than spectroscopic ones. The trigonometric parallaxes will serve for many of the dwarf stars but are quite unreliable for the giants. In our former publication we stated that we hoped the accidental error would be as low as 0·2 magnitude. We based our expectations on the accordances of the values obtained for the various lines and the number of lines used. As an indication of the error to be expected when the results are looked at in this way, we have taken every twentieth star in table 7 and computed the probable errors as shown below.

F-	type	19	stars	average p.e.	0·17 mag.
G	"	14	"	"	0·16 "
K	"	13	"	"	0·14 "
M	"	3	"	"	0·12 "

Unfortunately, as so often happens, this method does not give a very good indication of the true errors and further investigation seems to show that the errors are larger than we hoped.

We have taken all the stars for which the Victoria parallax was greater than or equal to 0·050. These were divided into three divisions with respect to type, namely A to G4 inclusive, G5 to K2 inclusive and K3 to M8. Each of these divisions was subdivided into three groups, according to absolute magnitude, the limits being 0 to 2, 2 to 4, and greater than 4. As so few stars occurred in the giant divisions they were amalgamated with the second. The absolute magnitude was computed from the trigonometric parallax and the algebraic and the arithmetic means taken. The means for the absolute magnitudes determined at Mount Wilson were also taken. Table 10 gives the results of this computation.

TABLE 10

No. Stars	Limits of Type	Limits of Abs. Mag.	(Vict.-Trig.) M		(Mt. W.-Trig.) M	
			Algebraic	Arithmetic	Algebraic	Arithmetic
35	up to G4 incl.	up to 4·0 incl.	+0·33	0·60	+0·10	0·50
42	"	4·1 and fainter	−0·16	0·49	−0·28	0·52
9	G5-K2	up to 4·0 incl.	+0·90	0·91	+0·74	0·80
32	"	4·1 and fainter	−0·04	0·44	+0·01	0·41
2	K3-M8	up to 4·0 incl.	+0·50	0·50	−0·25	1·45
8	"	4·1 and fainter	−0·16	0·24	−0·04	0·26

The average arithmetic residual for the stars shown in the table is 0·52 for Victoria and 0·50 for Mount Wilson. These residuals include the errors in the trigonometric parallaxes as well as the systematic errors in the two systems. The probable error corresponding to an average error of 0·50 is 0·42. This is in very close agreement with the estimate formed by the Mount Wilson observers in their publication of 1646 stars, where they placed the probable error at 0·40 magnitude. It is interesting to note that the 9 stars of types G5-K2 brighter than the fourth absolute magnitude confirm what has already been said as to the existence of a systematic error in the results for these stars.

The material of table 10 is based almost entirely on the dwarf stars. For the giant stars we were unable to get a good basis of comparison but we can get some idea of the accidental errors by a comparison with the Mount Wilson values. We have formed the difference Victoria minus Mount Wilson for the 553 stars common to the two lists and divided them into nine groups following much the same plan as in table 9 except that three more groups were added for the brightest stars.

The result of this comparison is shown in table 11.

TABLE 11

No. Stars	Limits of Type	Limits of Abs. Mag.	(Vict.-Mt. W.) M	
			Arithmetic	Algebraic
127	A4 to G4 incl.	Fainter than 3·0	0·45	0·18
69	"	2·9 to 0·0 incl.	0·73	0·26
26	"	Brighter than 0·0	0·95	0·01
49	G5 to K2 incl.	Fainter than 3·0	0·46	−0·01
146	"	2·9 to 0·0 incl.	0·73	−0·30
22	"	Brighter than 0·0	0·90	−0·60
9	K3 to M8 incl.	Fainter than 3·0	0·31	−0·01
33	"	2·9 to 0·0 incl.	0·54	+0·17
72	"	Brighter than 0·0	1·01	−0·97

The table shows that the accidental departures are greater in the giants than in the dwarfs for all spectral types and this was shown also as pointed out before in connection with the graphs shown in figures 10 to 14. The points in the diagrams in the lower left hand corners which are the giant stars, are more scattered than those in the upper right which represent the dwarfs. There are some systematic differences in the later type giants, our values being the more negative.

We have shown from the trigonometric parallaxes that the probable error which affects the Victoria absolute magnitudes is about the same as that affecting the Mount Wilson results for the same stars. In the diagrams ten to fourteen, this is equivalent to saying that to bring any star which does not lie on the central line into accordance the chances are that it should be moved horizontally and vertically about the same amount. This applies to the dwarfs. Suppose we divided all the giant stars into two classes; those for which the Victoria absolute magnitudes are more positive than the Mount Wilson and those for which the Victoria values are more negative. Proper motions ought to be able to distinguish which are the more reliable without being able to indicate the exact probable error of either. The division is equivalent to taking those stars which lie above the central line in one group and those below in another group. In order to make the difference between the groups as large as possible we have confined oursevles to all those stars which show a difference Victoria minus Mount Wilson of 1·0 magnitude or over. Practically all these stars are giants for the accordance of the two systems in the dwarfs makes a very small number of stars differ by an amount as large as this.

The stars were next divided according to types into three divisions.

1, up to and including G4.
2, G5 to K2 inclusive.
3, from K3 on.

Some of these divisions were further subdivided according to absolute magnitude forming ten groups in all as shown in table 12. The absolute magnitudes for these groups were computed in two ways, given under the headings M1 and M2. In the first of these computations we set a few stars aside which had very large proper motions and which had

trigonometric parallaxes. This seemed necessary because a few large proper motions in a group of stars has a preponderating effect on the result. Absolute magnitudes for the remaining stars were evaluated from the proper motion and combined with that from the trigonometric values for the other stars to give the values in the column headed M1. In the second method we sorted out all those stars with measured parallaxes which were trustworthy whether they had large proper motions or not. The two columns are in fair agreement. For some of the groups there were no good parallaxes and the two computations were unnecessary. For the later type giants at least the comparison is favourable to the Victoria absolute magnitudes.

TABLE 12

Type	Residual	Limits of Absolute Magnitude	No. Stars	Absolute Magnitudes			
				M1	M2	Victoria	Mt. Wilson
A8–G2.....	+	1·0 and fainter.....	11	2·67	2·84	3·71	2·33
F3–G4.....	+	0·9 and brighter.....	13	−1·32	−0·37	0·23	−1·38
F4–G4.....	−	0·0 and fainter.....	7	2·63	2·63	2·39	3·53
F4–G4.....	−	−0·1 and brighter.....	4	−3·90	.....	−2·90	−1·28
G5–K2.....	+	1·0 and fainter.....	18	1·19	1·05	1·70	0·86
G5–K2.....	+	0·9 and brighter.....	20	0·10	0·46	0·38	−0·60
G5–K2.....	−	all	21	1·23	.....	0·69	2·44
K3–K5.....	+	all	9	0·84	1·21	1·33	0·05
K3–M8.....	−	−0·3 and fainter.....	16	−0·01	.....	−0·74	0·68
K3–M8.....	−	−0·4 and brighter.....	15	−1·68	.....	−2·00	0·00

Fuzzy-Line Stars

In the course of measuring the stellar spectra for absolute magnitude we usually rejected all those stars which had very poorly defined lines but the degree of sharpness that was necessary before a certain star was included was rather elastic. One would expect that the stars with poorly defined lines would give large accidental errors. The number of stars is far too few to discuss this point but we thought it best to make a list of the stars and ascertain whether they were systematically correct or not.

For seventeen stars in which the lines are distinctly more fuzzy than the average the computed absolute magnitudes came out +2·04 whereas we obtained +1·24, both observers being about the same. It would seem, therefore, that the observed values are not excessively in error, though a positive correction is indicated. It is interesting to note that the correction is about of the size it would have if the diffuse character of the lines were caused by the presence of a blended spectrum formed from two stars of the same brightness.

IX—Suggestions for Future Work on Absolute Magnitude

It will be of interest to consider ways by which the methods used in determining absolute magnitudes may be improved. The various factors which enter into the problem are.

1. The quality of the spectra.
2. The number and character of the lines which show the desired effect.
3. The methods of measuring the intensities of the absorption lines.
4. The methods of obtaining the empirical reduction curves.

These various factors will be treated in turn.

1. *The quality of the spectra.*

The dispersion of the spectrograph is an important consideration. We have been using a single-prism instrument giving a dispersion of about 30 A at Hγ, and our experience would endorse this instrument for further work. If the time factor did not enter one would like to use as high dispersion as possible and a limited program of observation with a three-prism instrument would be well worth while. We do not think that plates taken with high dispersion could be reduced by the same reduction curves as those used for low dispersion, however, and consequently the field of the three-prism plates would be limited to investigations into the behaviour of the various lines while the problem of determining absolute magnitudes for the fainter stars must be solved with low dispersion.

It is obviously important that the spectra should be obtained of uniformly good quality. When plates are out of focus or if the slit is wider than usual or if the temperature changes during the exposure, the lines are not so sharp and crisp. This would not be of much importance in the intensity ratio of a pair of lines if both lines lost equally but a weak line loses much more than a strong one. We have taken considerable trouble to obtain good looking spectra of nearly all the standard stars but many of those that were taken on the Boss program for radial velocity were not of the best and no doubt more plates would improve the results for them.

Another factor is the method used for developing the plates. If these are over or underdeveloped the contrast of the lines seems to change. For some time past we have been using the factorial method of developing but for the program as a whole several developers and methods have been used so that the plates can not be considered uniform. We think it important too that the emulsion remain about the same. When plates showed by their appearance that they were either under or overdeveloped, under or overexposed, they could be discarded but even leaving these out, the remainder are probably not as uniform as desirable. Investigations[5] made by Dr. D. L. Edwards lead him to conclude that errors from this source were not important for normally exposed and developed plates. Our experience is in accord with this conclusion at least for the stronger lines but for the fainter lines it becomes more important and if the method is to gain in accuracy we think it important to standardize the development pretty carefully.

2. *The lines used for the determination of absolute magnitude.*

The first list[6] of absolute magnitudes derived spectroscopically rested on the measures of three lines. The number of lines was extended to five in the next publication[7] which contained 500 parallaxes.

Several other lines were shown to give an effect but none were considered good enough to include. Dr. W. B. Rimmer in a publication[8] giving the parallaxes for 500 stars added the important line λ 4444 and Adams and Joy in a further list published in the Publications of the Astronomical Society of the Pacific, December 1923, adds several more lines. These with the new ones given in this publication bring the number to more than two dozen and there is no doubt the list could be extended.

If a carefully prepared program of stars were re-observed and all these lines measured, there would be a considerable gain. At the same time the method of assigning the types of the stars would have to be standardized.

3. *The methods of measuring the intensities of the lines.*

The methods that have been used in the present work are fully described in section IV. These are fairly satisfactory and after using the method for about three years the advantages and objections to it have become fairly clear. It is a great step forward over simple eye estimates but it still lacks the mechanical features whereby several settings may be made and the mean taken. It is inferior to the method used by Mr. Rimmer in this respect but the extinction method used by him was well known objections. There is another difficulty connected with the method we have been using. When the step ratio is large for any pair of lines the intervening steps on the standard scale are confusing. We have in mind a device whereby these may be eliminated and at the same time the readings made mechanical. In the near future this will be tried out and it is hoped that the present scale can be reproduced with the added advantages of being able to make repeated settings. It is necessary that the measures of the lines be made with considerable dispatch, because there are so many to be made that unless each one takes a comparatively short time, headway will be made too slowly. This consideration probably prohibits too great refinements such as obtainable with a microphotometer.

4. *Methods of obtaining empirical reduction curves.*

The correct procedure to obtain reduction curves to convert from line intensity to absolute magnitude is very controversial and one in which various workers will disagree. For the nearby stars the trigonometric parallaxes are still the best standard we think. Departures of the spectroscopic values from these when well established should not be taken to mean that either are in error but rather that there is some disturbing factor such as mass. At present there are four estimates of spectroscopic absolute magnitude for a considerable number of stars and when these consistently give a parallax differing from the trigonometric and the latter is well established, the difference is probably real. Discordances between the spectroscopic values from one observatory and the trigonometric ones should not be given much weight unless it is very marked.

For the giant stars with small parallax, we think the best procedure will be to compute an absolute magnitude from the various spectroscopic values already published, due consideration being given to systematic corrections when these are evaluated. A set of absolute magnitudes of this kind will enable us to construct reduction curves for new lines giving results systematically the same as the mean of the systems already in use and these will further reduce the accidental values for the individual stars. The serious stumbling block to the final elimination of systematic errors from the most giant stars is going to be the errors in the proper motions and time alone can remove this. Take for instance stars of absolute magnitude -4. If their apparent magnitude is as faint as $6{\cdot}0$, and the number brighter than this is very limited, the parallax is only $\cdot 001$, which means that the expected proper motion is less than $\cdot 010$. Proper motions this small have a large proportional error, in fact Kapteyn has suggested a systematic correction which would reverse the sign of many of the proper motions in declination.

Description of Catalogue

In Table 7 which follows the various columns give the following data for each star.

Column 1 and 13 The serial number in this table.

2 The number in Boss' Preliminary General Catalogue or in the Harvard Revised Photometry, Vol. 50.

3 The name of the star or in case there was no Bayer name and the star was not in either Boss or Harvard 50, then this column contains the number in some well known authority such as Lalande or Cincinnati Publication No. 18.

4 and 5. Right Ascension and Declination for 1900.

6 The visual magnitude from the revised Draper catalogue. In the case of double stars or spectroscopic binaries this has been corrected to reduce the magnitude to the estimated apparent brightness of the brighter component. These stars are distinguished by the symbol†.

7 The estimated Victoria spectrum.

8 The total proper motion either from Cincinnati Publication No. 18 or Boss' Preliminary Catalogue. When taken from the latter the corrections given on page XXVIII have been added.

9 The radial velocity when corrected for the solar motion which was assumed to be 20 km. in a direction $\alpha = 270°$, $\delta = +30°$.

10—24. The absolute magnitudes derived for the star from the various lines. The upper lines are Young's values and the lower Harper's.

25 The algebraic means of the values in columns 10–24.

26 The absolute magnitude as published by the Mount Wilson Observatory in Contributions No. 199.

27 The Victoria estimated parallax as based on the mean absolute magnitude in column 24 and the visual magnitude in column 6.

28 The trigonometric parallax as used. By far the greater number of these are taken from Mount Wilson Contributions No. 199. Occasionally the values there given have been revised to include a later determination.

In some cases we consider the derived absolute magnitude uncertain either from the plates being underexposed or from other causes and these are usually distinguished by being followed by a colon. In many cases the spectra are peculiar and cases that seemed worthy of comment have been starred in the first column and notes will be found at the end of the table. In cases where the lines are poor or fuzzy, the star is distinguished by the letter *n* following the type.

TABLE

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
1	Boss 1	33 Piscium	00 00·2	−06 16	4·7	K0	·089	+ 2·9	2·8 2·2	1·9 2·4	....
2	Boss 2	86 Pegasi	00 00·6	12 51	5·7	G7	·038	+ 4·7	−0·3 0·0	1·2 1·8	....
3	Boss 3	.....	00 01·0	57 53	6·4†	G5	·266	− 5·8	4·3 3·0	5·0 5·1	....
4	Boss 6	Br 3212	00 01·4	28 29	6·2	G8	·422	− 3·0	4·2 3·0	6·2 6·7	....
5	H. R. 17	.....	00 03·5	36 04	6·1	F4	.....	.....	5·6 4·7	3·4 3·9	5·1 5·3
6	H.R. 19	.....	00 03·7	24 54	6·4	G9	.....	.....	−2·2 −1·2	1·4 1·4	....
7	Boss 12	β Cassiop.	00 03·8	58 36	2·4	F2	·561	+21·2	1·4 1·5	3·2 4·5	1·5 1·3
8	H.R. 36	.....	00 06·7	47 36	6·3	K5			....	....	....
9	Boss 29	23 Androm.	00 08·3	40 29	5·7	A7	·192	−23·7	2·8 3·0	2·9 3·9	3·0 2·5
10	Boss 31	χ Pegasi	00 09·4	19 39	4·9	M1	·097	+47·6	−1·4 1·1	....	....
11	Boss 45	38 Piscium	00 12·3	08 19	6·6	F8	·123	+37·1	7·0 4·9	4·0 4·1	4·6 4·5
12	.....	C 25	00 12·7	43 27	8·1	M0	2·890	+ 9·1	....	....	....
13	Boss 49	.....	00 12·7	01 08	6·4	G8	·076	−10·2	2·2 1·4	3·5 2·6	....
14	Boss 53	ι Ceti	00 14·3	−09 23	3·8	K3	·040	+16·4	....	....	....
15	Boss 54	40 Piscium	00 14·8	15 42	6·8	G9	·015	+20·4	2·3 1·8	1·0 2·0	....
16	Boss 57	μ Androm.	00 15·9	37 25	5·2	F4	·080	+12·8	0·4 0·7	0·6 1·6	2·3 1·0
17	Boss 73	44 Piscium	00 20·3	01 23	6·0	G4	·025	− 5·1	....	0·9 1·0	..... −1·0
18	Boss 80	46 Piscium	00 22·8	18 58	6·6	K2	·017	+ 7·9	..... −1·1	−1·0 1·2	....
19	H.R. 110	.....	00 23·7	36 21	6·4	G5	.....	.....	1·2 3·4	3·2 2·5	..... 1·2
20	Boss 89	28 Androm.	00 24·8	29 12	5·3	F1	·069	− 7·9	3·0 2·8	4·0 4·6	2·9 1·5
21	Boss 96	.....	00 26·2	52 17	5·7	K0	·056	−48·8	0·9 1·0	1·2	....
22	Boss 106	.....	00 27·6	27 44	6·4	G6	·016	−10·4	1·8 0·8	2·0	....
23	Boss 126	.....	00 32·2	81 56	6·4	F7	·141	−25·1	5·3 4·4	3·5 3·3	4·3 3·6
24	Boss 130	ϵ Androm.	00 33·3	28 46	4·5	G3	·336	−80·4	2·3 3·0	0·8 1·3	3·8 5·0

7

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1	2·4	1·0	1·7	1·6	0·0	2·2	−1·2	1·4	0·8	1·6	.....	1·4	.....	·025	
	1·4	1·9	2·5	0·9	2·4	2·5	0·0	3·4	2·0	2·0	.....	2·0			
2	0·5	1·2	1·2	1·7	0·2	0·9	1·2	1·1	1·6	1·7	.....	1·0	.....	·020	
	1·0	0·8	1·4	−0·2	2·2	1·0	0·5	1·3	2·4	2·1	.....	1·3			
3	4·7	5·5	4·0	4·9	4·8	.....	.....	.....	.....	.....	.....	4·8	5·3	·051	·036
	6·8	6·4	5·4	5·7	3·7	5·4	5·2	4·0	.....	.....	.....	5·1			
4	5·6	4·9	3·9	5·5	.....	.....	.....	.....	.....	.....	.....	5·0	5·8	·062	·150
	4·6	4·5	5·7	5·7	.....	6·5	5·7	6·0	.....	.....	.....	5·3			
5	.....	.....	5·5	5·3	5·4	.....	.....	.....	.....	.....	.....	5·0	.....	·054	
	.....	.....	4·0	4·4	4·6	.....	.....	.....	.....	.....	.....	4·5			
6	.....	.....	0·2	1·4	0·8	1·3	−1·2	0·0	−0·6	0·1	.....	0·1	.....	·006	
	.....	2·0	0·8	1·2	0·8	1·6	−1·4	−0·3	−1·4	−0·2	.....	0·3			
7	.....	.....	0·8	.....	1·0	.....	.....	.....	.....	.....	.....	1·6	1·6	·072	·071
	.....	.....	1·5	.....	0·5	.....	.....	.....	.....	.....	.....	1·8			
8	1·8	0·0	.....	−0·3	.....	.....	−0·7	0·3	−0·3	−0·3	.....	0·1	.....	·005	
	1·0	.....	−2·3	−1·2	.....	0·9	0·3	0·4	−1·2	−0·4	−0·8	−0·4			
9	.....	.....	4·5	5·2	3·7	.....	.....	.....	.....	.....	.....	3·7	.....	·034	
	.....	.....	2·8	2·8	2·8	.....	.....	.....	.....	.....	.....	3·0			
10	.....	.....	.....	+0·3	.....	−0·3	0·1	0·7	0·9	−0·1	−0·2	0·0	0·0	·010	·015
	.....	−0·3	0·0	−0·4	.....	−0·7	−1·3	2·0	−0·2	−0·7	−1·4	−0·2			
11	.....	.....	.....	2·2	3·9	4·5	.....	.....	.....	.....	.....	4·4	.....	·032	
	4·9	.....	1·0:	1·2:	2·4:	.....	.....	.....	.....	.....	.....	3·8			
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	·280
	9·6	8·8	.....	.....	.....	.....	.....	8·6	9·7	10·0	.....	.....			
13	1·2	0·8	3·8	2·3	1·7	1·0	2·0	1·6	1·2	2·5	.....	2·0	.....	·012	
	1·6	2·4	−0·6	−0·6	0·4	.....	0·7	1·5	2·3	4·0	.....	1·4			
14	−0·2	−1·4	.....	−1·6	.....	.....	−1·4	−1·4	−1·4	1·0	.....	−0·9			
	.....	−0·5	−2·8	−2·7	.....	.....	−0·6	0·0	−1·0	2·4	−0·9	−0·8	0·6	·012	
15	1·7	1·9	3·8	2·3	2·2	2·1	2·0	1·4	2·4	3·2	.....	2·2			
	2·2	1·7	0·9	0·3	.....	0·4	1·5	1·1	.....	2·8	.....	1·5	.....	·010	
16	.....	.....	3·2	3·9	2·5	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	2·5	2·6	2·2	.....	.....	.....	.....	.....	.....	1·8	.....	·022	
17	−0·2	0·0	−0·8	0·8	1·8	−0·1	.....	−1·0	−0·3	.....	.....	0·1			
	0·3	0·4	.....	0·2	.....	.....	1·3	0·8	−0·2	0·3	.....	0·3	.....	·007	
18	1·5	1·6	0·7	−1·5	1·3	−0·5	2·8	0·7	0·8	0·8	.....	0·7			
	2·3	1·8	−1·7	−0·2	1·7	−1·5	2·9	2·6	0·2	0·8	1·0	0·8	.....	·007	
19	2·0	2·7	1·5	1·9	0·7	0·5	0·0	0·5	0·0	2·0	.....	1·4			
	4·0	3·1	0·4	−0·8	1·0	0·2	2·0	.....	.....	.....	.....	1·7	.....	·011	
20	.....	.....	2·7	1·9	2·3	.....	.....	.....	.....	.....	.....	2·8			
	.....	.....	2·8	2·9	1·9	.....	.....	.....	.....	.....	.....	2·8	2·5	·032	
21	−0·8	0·4	2·0	−0·4	.....	0·8	−1·2	−0·2	−0·9	0·8	.....	0·2			
	−1·3	−0·5	1·2	1·1	−1·8	−0·4	−0·8	0·9	1·4	1·3	−0·2	0·2	0·3	·008	
22	0·6	0·7	1·8	−1·8	1·8	−0·1	−0·5	−0·5	0·1	0·9	.....	0·6			
	.....	.....	3·0	1·5	1·4	−2·2	−0·1	−1·0	.....	.....	.....	0·5	−0·2	·007	·005
23	4·5	.....	2·6	3·2	4·4	.....	.....	.....	.....	.....	.....	4·0			
	6·9	.....	2·3	.....	3·8	.....	.....	.....	.....	.....	.....	4·0	.....	·033	
24	1·4	.....	0·6	−0·1	1·8	.....	.....	.....	.....	.....	.....	1·5			
	3·3	.....	−1·9	−2·7	2·1	.....	.....	.....	.....	.....	.....	1·4	0·2	·025	·063

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TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	°							
25	Boss 132	δ Androm.	00 34·0	30 19′	3·5	K3	·166	+ 7·9	3·8 3·2	3·1 2·1	....
26	Boss 133	54 Piscium	00 34·2	20 43	6·1	K1	·595	−32·7	6·9 6·9	5·5 4·1	....
27	Boss 134	55 Piscium	00 34·6	20 54	5·6	K0	·049	−17·0	1·0 0·4	1·8 2·2	....
28	Boss 135	α Cassiop.	00 34·8	55 59	2·5	G7	·062	+ 3·8	0·1 0·2	−1·5 −1·0	....
29*	Boss 140	.....	00 36·3	24 05	6·0	A+F	·111	−15·6	−0·9 0·8	4·1 3·3	−1·5 1·7
30	Boss 161	57 Piscium	00 41·3	14 55	5·6	M6	·064	−26·4	....	..... −0·8	....
31	Boss 164	ζ Androm.	00 42·0	23 43	4·3	G6	·128	−28·6	2·2 2·2	2·8 2·4	....
32	Boss 167	61 Piscium	00 42·6	20 23	6·6	F8	·164	− 0·6	1·7 3·3	2·6 3·5	4·5 2·9
33	Boss 168	η Cassiop. (br)	00 43·0	57 17	3·7	F8	1·245	+16·7	7·1 5·7	5·0 4·6	5·4 5·0
34	.....	η Cassiop. (ft)	00 43·0	57 17	7·4	K6:	1·245	+16·6	....	....	....
35	Boss 171	.....	00 43·1	04 46	5·8	K4	1·370	−11·2	..... 10·0	7·5 6·5	....
36	Boss 173	δ Piscium	00 43·5	07 02	4·6	K5	·097	+30·5	..... −0·6	....	....
37*	Boss 179	.....	00 44·7	63 42	6·0†	A+F	·032		4·9 4·2	−1·0 0·1	5·0 4·1
38	Boss 188	.....	00 46·2	02 50	6·5	G5	·089	+ 1·6	....	....	....
39	Boss 191	20 Ceti	00 47·9	−01 41	4·9	K7	·018	+12·3	....	....	....
40	H.R. 249	.....	00 48·0	36 53	6·1	K3	.....	.....	0·3 1·6	0·8 0·8	....
41	Boss 192	.....	00 48·1	52 09	6·2	A4	·090	+ 4·5	0·5 1·0	2·1 3·0	0·0 2·3
42	H.R. 259	.....	00 49·9	24 01	6·4	M7			....	....	....
43	Boss 200	28 Cassiop.	00 50·7	58 38	4·8	G5	·099	−40·1	1·6 2·5	0·7 0·2	....
44	Boss 206	η Androm.	00 51·9	22 52	5·0†	G7	·060	−11·7	2·3 2·4	0·9 0·1	....
45	H.R. 272	.....	00 52·0	45 18	6·2	K2			....	..... 1·2	....
46	Boss 226	ε Piscium	00 57·8	07 21	4·4	G6	·082	+ 4·8	0·8 1·6	1·7 1·0	....
47	Boss 234	72 Piscium	00 59·8	14 24	5·6	F4	·042	+ 4·3	−0·4 0·5	0·7 0·8	1·4 2·1
48	Boss 238	77 Piscium	01 00·7	04 22	6·8	F3	·117	− 8·6	3·2 2·4	2·0 3·8	4·1 3·7

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
25	0·6	1·4	2·2	1·0	.....	1·0	−1·7	−0·5	0·5	2·7	.....	1·3			
	−0·2	−0·6	2·2	2·6	0·8	1·9	−1·3	−0·4	1·4	1·3	1·0	1·1	0·8	·036	·020
26	5·8	4·0	4·8	4·2	.....	.....	.....	6·3	.....	5·7	.....	5·5			
	5·1	4·6	3·9	4·2	7·5	5·5	5·1	5·3	6·2	6·0	4·3	5·5	6·2	·076	·111
27	−0·6	−0·3	1·0	0·7	3·3	2·6	−0·2	−0·2	0·0	1·0	.....	0·8			
	0·6	0·5	−1·0	−1·2	−0·3	0·8	0·0	−0·3	0·0	0·7	0·4	0·2	.....	·010	
28	0·0	0·6	0·5	−0·4	1·3	2·0	0·5	−1·1	−1·9	−0·8	.....	−0·1			
	−3·0	0·5	3·1	1·2	.....	0·6	−0·6	−0·6	.....	.....	.....	0·0	−1·0	·031	·040
29	.....	.....	+6·0	1·7	−2·2	.....	.....	.....	.....	.....	.....				
	.....	.....	3·3	2·0	−0·6:	.....	.....	.....	.....	.....	.....				
30	.....	.....	.....	−2·0	.....	−1·2	0·7	−0·6	−0·4	−0·6	−1·6	−0·8			
	.....	−1·5	−1·5	−0·5	.....	−1·2	−0·9	−1·0	−1·5	−0·5	−1·2	−1·1	0·4	·005	·014
31	0·9	1·7	3·5	1·3	0·9	0·5	−0·3	−0·9	−0·6	1·3	.....	1·1			
	2·8	0·2	3·6	1·2	0·3	0·3	−0·2	−0·6	.....	.....	.....	1·2	0·8	·023	·031
32	4·4	.....	4·7	2·7	4·5	.....	.....	.....	.....	.....	.....	3·6			
	1·9	.....	3·4	2·5	4·1	.....	.....	.....	.....	.....	.....	3·1	.....	·022	
33	5·0	.....	5·1	5·7	5·1	.....	.....	.....	.....	.....	.....	5·5			
	4·3	.....	5·0	5·1	4·4	.....	.....	.....	.....	.....	.....	4·9	4·3	·200	·186
34	7·6	8·5	.....	.....	.....	.....	.....	.....	9·0	8·3	.....	8·3			
	7·8	8·2	.....	.....	.....	.....	7·8	6·9	9·2	8·1	7·8	8·0	8·3	·141	·186
35	8·5	7·9	.....	7·1	.....	.....	5·9	6·0	6·6	6·9	.....	7·0			
	6·9	7·0	8·1	6·0	6·7	6·8	7·0	6·6	6·4	5·4	6·2	6·9	6·5	·170	·170
36	1·5	−1·0	.....	0·0	.....	−2·4	0·2	1·3	−0·9	−0·7	.....	−0·2			
	.....	−0·5	−1·2	0·4	.....	.....	−0·3	−0·3	−0·8	−0·8	−0·8	−0·5	0·9	·010	·017
37	.....	.....	.....	−0·7	0·3	.....	.....	.....	.....	.....	.....	1·7:			
	.....	.....	4·1	−0·4	2·4	.....	.....	.....	.....	.....	.....	2·4:	.....	·016	
38	0·0	1·2	.....	−1·2	.....	.....	−1·0	−1·2	−1·0	0·3	.....	−0·4:			
	0·6	0·8	−0·8	−1·5	.....	.....	−0·2	0·3	1·3	0·2	.....	0·1:	.....	·005	
39	0·8	0·0	.....	−0·7	.....	−1·8	−1·2	0·1	−1·0	−1·2	.....	−0·6:			
	.....	.....	−1·5	0·0	.....	−0·1	0·6	−0·2	−1·8	−0·5	.....	−0·5:	0·3	·008	
40	0·8	0·0	.....	−0·8	0·0	−0·5	0·6	1·0	0·2	2·4	.....	0·4			
	0·6	−0·5	−0·9	−0·8	0·9	0·8	1·6	1·2	1·4	2·6	.....	0·8	.....	·008	
41	.....	.....	6·0	3·0	0·0	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	3·3	1·8	0·2	.....	.....	.....	.....	.....	.....	1·9	.....	·014	
42	.....	.....	.....	−2·0	.....	−0·1	.....	−3·0	0·2	−2·5	−2·1	−1·6:			
	.....	−1·6	.....	.....	.....	.....	−3·0	−0·6	−1·6	−0·7	−2·4	−1·6:	.....	·003	
43	1·4	1·0	1·8	−0·4	0·2	0·3	.....	−0·1	−0·9	−0·1	.....	0·5			
	1·3	1·1	0·0	−1·6	1·0	−1·0	.....	−0·4	−0·6	0·0	.....	0·2	0·7	·013	·073
44	−0·4	0·6	0·9	0·8	1·8	2·0	1·8	1·8	2·4	0·7	.....	1·3			
	1·2	0·2	3·1	2·9	1·3	2·2	1·0	0·7	.....	.....	.....	1·5	0·5	·019	·011
45	0·5	0·0	.....	−0·8	.....	−1·6	0·8	2·0	0·5	1·9	.....	0·5			
	0·9	−0·4	−1·8	−1·9	0·4	1·5	3·2	2·1	2·3	3·0	2·4	1·1	.....	·008	
46	1·0	1·0	1·0	0·3	0·6	0·0	0·2	0·2	0·2	−0·4	.....	0·5			
	0·6	.....	1·7	−0·6	1·2	−1·3	0·4	0·6	.....	−0·2	.....	0·4	0·2	·016	·027
47	.....	.....	1·7	2·4	1·4	.....	.....	.....	.....	.....	.....	1·2			
	.....	.....	2·1	1·4	1·4	.....	.....	.....	.....	.....	.....	1·4	.....	·014	
48	.....	.....	5·2	5·0	2·3	.....	.....	.....	.....	.....	.....	3·6			
	.....	.....	4·3	3·3	2·8	.....	.....	.....	.....	.....	.....	3·4	.....	·022	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	°							
49	Boss 239	.....	01 00·7	79 29′	6·4	G8	·052	−18·6	3·4 2·0	0·6 1·8	....
50	Boss 241	76 Piscium	01 00·7	31 39	6·6	K4	·023	+28·3	..... 1·4:	....	....
51	Boss 244	μ Cassiop.	01 01·6	54 26	5·3	G5	3·762	−91·9	7·1 5·5	6·9 6·6	....
52	Boss 248	78 Piscium	01 02·4	31 29	6·3	F2n	·200	+11·3	1·8 2·3	1·7 3·0	1·6 1·3
53	.....	Lal. 1985	01 04·0	67 15	6·6	F9	·236	− 4·5	4·2 4·0	2·2 3·1	5·1 4·8
54	Boss 259	β Androm.	01 04·1	35 05	2·4	M0	·218	+ 1·9	0·3 0·0	..... −0·6	....
55	Boss 262	44 Androm.	01 04·6	41 33	5·7	G0	·143	−10·1	2·6 2·3	2·1 2·1	4·0 3·2
56	H.R. 344	.....	01 05·0	15 09	6·4	K6			....	....	....
57	Boss 264	θ Cassiop.	01 05·0	54 37	4·5	A5	·232	+19·3	0·9 1·2	0·6 1·2	4·3 3·6
58	Boss 270	χ Piscium	01 06·1	20 30	4·9	G6	·022	+14·8	−0·2 0·5	+0·5 −0·6:	....
59	Boss 271	τ Piscium	01 06·2	29 34	4·7	K2	·084	+30·2	1·8 2·4	..... 0·0	....
60	Boss 281	ϕ Piscium	01 08·3	24 03	4·6	K1	·050	+ 4·3	2·5 1·6	0·7 2·1	....
61	Boss 283	.....	01 08·5	07 03	6·5	F7	·147	+21·2	3·2 4·3	5·0 4·6	4·0 2·8
62	H.R. 379	.....	01 13·1	36 52	6·3	A9	.....	.....	−0·9 −1·4	0·3 0·1	1·1 0·2
63	Boss 304	ξ Androm.	01 16·4	45 00	5·0	K1	·043	− 6·9	2·1 1·6	1·0 1·8	....
64*	Boss 307	47 Androm.	01 17·9	37 12	6·3†	A3	·078	+15·8	0·0 0·2	1·4 2·7	2·7 2·2
65	Boss 313	θ Ceti	01 19·0	−08 42	3·8	K0	·228	+10·1	2·0 1·9	0·0 0·0	....
66	H.R. 407	.....	01 20·1	23 00	6·1	F4	.....	.....	1·4 2·6	3·2 3·4	2·0 2·0
67	H.R. 410	.....	01 20·4	34 04	6·3	F5	.....	.....	4·8 4·3	2·5 3·0	5·6 4·6
68	Boss 318	ρ Piscium	01 20·9	18 39	5·3	A9	·038	−11·8	3·9 3·2	0·6 2·3	1·4 2·0
69	Boss 321	ω Androm.	01 21·7	44 53	5·0	F3	·360	+14·1	2·8 4·0	1·7 2·0	4·4 4·0
70	Boss 325	α Ursae Min.	01 22·6	88 46	2·1	F7	·042	− 4·8	−3·0 −2·9	..... −1·8	−3·3 −3·5
71	Boss 327	38 Cassiop.	01 23·8	69 45	6·0	F6	·159	+ 9·4	2·7 4·1	4·1 3·0	3·8 4·0
72	Boss 330	49 Androm.	01 24·1	46 30	5·3	G9	·047	− 8·2	0·0 2·5	2·7 2·4	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
49	2·1	4·0	−0·5	0·8	1·8	0·1	.....	.....	.....	.....	.....	1·5			
	2·1	3·0	−1·8	−1·0	0·2	−1·1	1·1	1·0	.....	−1·0	.....	0·6	.....	·009	
50	−0·5	0·5	−3·6	−2·4	.....	−2·7	−1·3	−0·7	−1·3	−0·7	.....	−1·4			
	−1·2	−2·9	−2·5:	−2·3	.....	−2·9:	−2·1	−0·2	−0·8	1·0	−1·5	−1·3	.....	·003	
51	7·6	5·8	4·6	6·6	7·0	.....	.....	.....	.....	.....	.....	6·5			
	6·7	5·4	3·8	5·2	4·9	6·4	5·1	5·5	.....	.....	.....	5·5	5·6	·138	·127
52	.....	.....	1·8	2·5	.....	.....	.....	.....	.....	.....	.....	1·9:			
	.....	.....	−0·7:	1·3:	3·3:	.....	.....	.....	.....	.....	.....	1·9:	.....	·013	
53	.....	.....	1·5	4·7	3·6	.....	.....	.....	.....	.....	.....	3·6			
	3·5	.....	2·2	4·0	3·2	.....	.....	.....	.....	.....	.....	3·5	4·0	·025	·023
54	.....	.....	.....	0·0	.....	1·0	0·8	0·1	0·0	0·2	0·2	0·3			
	.....	.....	0·0	−0·2	.....	0·1	1·2	−0·8	−0·9	−0·9	0·0	−0·2	0·5	·034	·049
55	4·0	.....	1·7	2·7	2·4	.....	.....	.....	.....	.....	.....	2·8			
	3·4	3·4	1·6	0·9	2·7	.....	.....	.....	.....	.....	.....	2·5	.....	·025	
56	−0·2	0·0	.....	.....	.....	.....	−1·4	−0·1	0·5	0·4	.....	−0·2			
	0·7	−1·9	.....	.....	.....	.....	−1·2	−1·8	−1·8	0·4	−0·2	−0·8	.....	·004	
57	.....	.....	1·0	.....	.....	.....	.....	.....	.....	.....	.....	1·7:			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2·0:	.....	·030	·026
58	−0·3	1·0	0·5	1·9	0·6	0·7	0·5	0·7	2·4	1·3	.....	0·8			
	−0·4:	−0·3	1·3	1·5	.....	0·3	0·5	0·2	.....	.....	.....	0·4	0·0	·014	·013
59	0·5	2·5	−0·5	0·5	1·7	0·0	2·4	2·3	−0·3	0·8	.....	1·1			
	1·2	2·4	−0·8	−1·1	1·7	1·5	3·4	3·2	−0·3	0·0	−1·5	0·9	0·5	·018	
60	0·0	1·8	1·0	−0·4	1·7	0·1	2·3	−0·2	−0·9	1·0	.....	0·8			
	0·6	1·7	0·6	0·4	1·8	1·0	2·4	1·4	−2·6	2·3	0·1	1·0	0·4	·018	
61	4·7	.....	4·9	4·8	3·6	.....	.....	.....	.....	.....	.....	4·3			
	5·5	.....	2·7	2·1	3·6	.....	.....	.....	.....	.....	.....	3·7	.....	·032	
62	.....	.....	.....	−0·2	−1·2	.....	.....	.....	.....	.....	.....	−0·2			
	.....	.....	3·1	−0·2	−0·8	.....	.....	.....	.....	.....	.....	0·2	.....	·006	
63	0·0	1·4	2·0	0·6	0·8	1·6	3·7	2·3	0·2	1·6	.....	1·4			
	0·6	0·8	0·6	0·4	1·8	2·6	3·2	1·4	0·6	2·5	1·0	1·4	1·0	·019	
64	.....	.....	6·0	.....	1·1	.....	.....	.....	.....	.....	.....	2·2			
	.....	.....	3·3	2·4	1·2	.....	.....	.....	.....	.....	.....	2·0	.....	·014	
65	2·7	1·5	2·8	−0·2	1·0	2·4	2·5	1·8	0·2	1·7	.....	1·5			
	2·6	1·6	−0·6	1·1	1·6	1·8	1·4	1·7	0·0	1·6	.....	1·2	0·3	·032	·101
66	.....	.....	0·9	2·5	1·0	.....	.....	.....	.....	.....	.....	1·8			
	.....	.....	1·8	2·5	0·6	.....	.....	.....	.....	.....	.....	2·1	.....	·015	
67	3·4	.....	3·7	4·8	4·2	.....	.....	.....	.....	.....	.....	4·1			
	.....	.....	2·2	2·2	3·8	.....	.....	.....	.....	.....	.....	3·4	.....	·031	
68	.....	.....	4·2	4·2	2·5	.....	.....	.....	.....	.....	.....	2·8			
	.....	.....	2·8	2·5	3·8	.....	.....	.....	.....	.....	.....	2·8	2·7	·032	
69	.....	.....	2·8	3·8	1·9	.....	.....	.....	.....	.....	.....	2·9			
	.....	.....	3·6	4·0	3·3	.....	.....	.....	.....	.....	.....	3·5	2·6	·044	·022
70	.....	.....	−1·4	−0·8	−2·2	.....	.....	.....	.....	.....	.....	−2·1			
	.....	.....	−1·3	−2·4	−2·8	.....	.....	.....	.....	.....	.....	−2·4	−3·0	·013	·041
71	.....	.....	4·8	5·8	3·3	.....	.....	.....	.....	.....	.....	4·0			
	3·6	.....	5·4	4·9	3·8	.....	.....	.....	.....	.....	.....	4·1	3·7	·041	·039
72	2·5	0·8	−1·2	−1·6	0·0	−1·5	−0·4	1·9	0·0	0·5	.....	0·3			
	0·8	−0·2	0·4	−0·9	2·1	−1·6	−0·3	1·1	0·5	2·4	.....	0·8	.....	·011	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
73	Boss 332	μ Pisicum	01 24·9	05 38′	5·1	K6	·297	+30·2	.....	.....	.....
									0·8	.....	.....
74	Boss 335	η Piscium	01 26·1	14 50	3·7	G5	·034	+11·8	−0·8	0·0	.....
									−0·5	−2·2	.....
75	Boss 338	χ Cassiop.	01 27·4	58 44	4·9	G6	·038	+11·3	1·8	1·6	.....
									3·0	0·1	.....
76	Boss 346	.....	01 30·3	48 12	6·2	K3	·015	−39·7	.....	1·6	.....
									0·0	1·9:	.....
77	Boss 350	υ Androm.	01 30·9	40 54	4·2	F8	·420	−25·7	3·9	3·9	4·5
									4·3	3·2	4·8
78	Boss 357	υ Persei	01 31·9	48 07	3·8	K3	·130	+19·1	0·6	.....	.....
									4·3	−0·8:	.....
79	Boss 367	105 Piscium	01 34·3	15 54	6·1	K1	·076	+13·2	1·6	.....	.....
									0·2:	3·8	.....
80	Boss 368	.....	01 34·7	42 47	6·3†	F1	·142	− 0·3	1·0	2·8	0·5
									1·6	3·0	1·9
81	Boss 372	.....	01 35·7	42 07	5·1	G2	·822	+ 6·6	5·4	4·7	5·0
									5·5	4·4	5·3
82	Boss 373	.....	01 35·7	25 14	7·0†	F4	·138	+ 2·6	4·2	2·7	5·0
									4·4	3·0	4·7
83	Boss 378	ν Piscium	01 36·2	04 59	4·7	K5	·018	− 5·3	1·4	.....	.....
									2·1	.....	.....
84	Boss 382	107 Piscium	01 37·1	19 47	5·3	K1	·735	−37·6	7·8	6·5	.....
									6·4	6·6	.....
85	H.R. 504	.....	01 38·3	45 39	6·5	K6			.....	.....	.....
									.....	.....	.....
86	Boss 391	τ Ceti	01 39·4	−16 28	3·6	G7	1·912	−25·9	5·9	7·9	.....
									5·9	6·6	.....
87	Boss 393	ο Piscium	01 40·1	08 39	4·5	G6	·086	+ 8·3	1·0	0·7	.....
									1·6	0·8	.....
88	Boss 394	.....	01 40·4	63 22	5·7	K0	·635	+ 7·6	6·6	6·2	.....
									7·0	6·8	.....
89	Boss 402	.....	01 42·7	37 27	6·0	G8	·116	+36·1	2·1	2·1	.....
									1·2	2·9	.....
90	Boss 409	.....	01 44·6	51 27	5·9	F3	·123	−15·3	4·9	2·0	5·0
									4·4	2·4	3·8
91	Boss 420	55 Androm.	01 47·3	40 14	5·6	K2	·011	− 5·7	−0·9	0·8	.....
									0·1	−0·2	.....
92	Boss 421	α Triang.	01 47·4	29 06	3·6	F2	·235	−14·6	2·0	1·2	2·0
									1·1	0·8	0·6
93	Boss 426	ξ Piscium	01 48·4	02 42	4·8	G7	·034	+23·6	2·5	1·7	.....
									2·4	1·4	.....
94	Boss 428	β Arietis	01 49·1	20 19	2·7	A3	·144	− 4·5	0·7	2·8	2·7
									0·8	3·9	2·9
95	Boss 435	.....	01 50·7	01 21	6·2	G0	·241	+18·1	3·4	4·7	6·0
									2·6	4·2	4·2
96	Boss 439	3 Persei	01 52·2	48 43	5·8	K0	·040	+ 2·1	3·1	1·8	.....
									2·0	2·6	.....

Continued

No.	4455 62	4455 94	4217 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
73	0·8	−0·4	.....	−1·1	.....	−2·2	0·4	0·5	−1·0	0·8	.....	−0·5			
	0·2	.....	−0·4	−0·2	−0·6	0·6	0·1	0·7	0·1	0·2	0·0	0·1	0·5	·609	
74	+0·7	−0·1	0·1	1·1	0·2	0·7	−1·3	0·6	2·4	0·3	.....	+0·1			
	1·6	0·0	1·8	0·8	.....	−1·0	−0·8	0·6	.....	.....	.....	−0·1	−0·4	·018	·022
75	1·3	2·3	−0·6	−1·3	−1·0	−0·8	0·8	1·6	0·2	0·3	.....	0·5			
	−1·6	.....	0·6	0·3	0·2	−1·6	1·1	1·6	.....	.....	.....	0·4	−0·1	·013	·020
76	.....	.....	2·1	−1·0	.....	−1·6	2·7	−0·4	−1·4	0·7	.....	0·3			
	.....	.....	−2·4	0·2	−2·2	−1·2	1·3	1·8	0·2	1·1	0·0	0·1	.....	·006	
77	4·1	.....	2·7	4·8	3·3	.....	.....	.....	.....	.....	.....	3·9			
	3·0	.....	5·0	3·7	4·4	.....	.....	.....	.....	.....	.....	4·0	3·7	·090	·057
78	0·8	1·2	.....	0·7	.....	1·1	1·5	2·0	0·8	3·7	.....	1·4			
	1·5	1·1	1·1	1·3	1·2	1·6	0·4	0·8	2·3	2·4	1·7	1·5	0·5	·034	·034
79	1·2	0·4	1·4	−0·1	3·8	0·8	−0·9	1·2	0·4	0·5	.....	0·9			
	1·8	1·2	−2·2	−2·0	0·4:	1·0	−1·8	0·8	1·4	0·6	−1·6	0·2	.....	·008	
80	.....	.....	1·0	.....	1·1	.....	.....	.....	.....	.....	.....	1·3			
	.....	.....	2·1	2·4	1·7	.....	.....	.....	.....	.....	.....	2·1	.....	·012	
81	5·3	3·6	5·0	.....	4·1	.....	.....	.....	.....	.....	.....	4·7			
	4·7	3·9	4·3	5·1	4·1	.....	.....	.....	.....	.....	.....	4·7	4·8	·083	·098
82	.....	.....	5·1	5·2	1·5	.....	.....	.....	.....	.....	.....	3·9			
	2·8	5·2:	4·0	.....	.....	.....	.....	.....	.....	.....	.....	3·9	2·6	·024	·036
83	.....	.....	1·1	−0·3	.....	0·0	−0·7	−1·2	−0·9	−0·5	.....	−0·1			
	1·2	.....	−0·1	0·7	1·9	0·2	−0·3	−0·3	−0·5	−0·5	0·3	0·4	0·8	·012	·055
84	6·0	5·3	6·0	6·8	7·1	.....	.....	.....	5·2	5·4	.....	6·2			
	5·8	5·6	5·4	6·7	5·8	5·2	4·9	5·4	5·6	5·9	4·9	5·7	5·8	·135	·142
85	−0·2	0·0	.....	−0·6	.....	.....	−1·2	−0·1	0·8	1·8	.....	0·1			
	1·4	−0·5	−1·6	−1·4	.....	.....	1·9	−0·2	0·6	2·6	2·2	0·6	.....	·006	
86	.....	.....	3·7	6·2	7·0	.....	.....	.....	.....	.....	.....	6·1			
	5·5	6·6	4·6	2·9	7·1	4·9	6·0:	6·9:	.....	.....	.....	5·8	6·1	·295	·317
87	1·6	1·6	0·8	−0·3	1·8	0·9	0·2	−0·2	−0·3	1·3	.....	0·8			
	.....	0·1	2·3	2·9	.....	−0·4	0·9	1·0	1·5	0·7	.....	1·1	0·0	·019	·017
88	6·8	5·2	5·6	6·7	5·9	.....	.....	.....	6·0	5·9	.....	6·1			
	6·5	6·0	7·1	8·2	5·9	6·1	4·5	5·6	6·4	5·2	5·7	6·2	5·6	·123	·089
89	0·5	1·0	1·1	0·2	0·0	0·7	0·4	2·1	3·1	2·5	.....	1·3			
	2·0	2·3	0·8	−0·8	−0·5	−1·0	0·4	−1·2:	.....	0·9	.....	0·7	.....	·010	
90	.....	.....	3·6	4·0	2·1	.....	.....	.....	.....	.....	.....	3·6			
	.....	.....	3·3	2·4	2·5	.....	.....	.....	.....	....	.....	3·1	.....	·031	
91	1·1	0·0	2·3	−0·5	−0·4	0·4	−2·0	−0·7	−0·3	−1·0	.....	−0·1			
	.....	−0·2	−0·5	−0·2	0·0	0·1	−1·2	−1·0	−1·1	−0·5	−1·5	−0·5	0·5	·007	·006
92	.....	.....	0·8	4·2	1·0	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	1·7	2·7	1·2	.....	.....	.....	.....	.....	.....	1·4	1·2	·041	·050
93	3·7	1·6	1·8	3·0	0·9	2·0	0·0	0·5	0·5	2·0	.....	1·7			
	3·4	1·3	3·1	2·0	1·8	2·4	2·0	.....	0·4	2·3	.....	2·0	0·7	·026	
94	.....	.....	2·3	.....	.....	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	2·0	.....	.....	.....	.....	.....	.....	.....	.....	2·4	.....	·082	·095
95	5·1	.....	2·8	3·7	4·0	.....	.....	.....	.....	.....	.....	4·2			
	4·3	5·6	3·8	2·7	2·7	.....	.....	.....	.....	.....	.....	3·8	.....	·036	
96	2·4	0·9	2·2	−0·4	1·2	−1·0	1·7	.....	.....	.....	.....	1·3			
	1·8	1·6	0·3	−0·2	1·7	0·4	2·2	2·7	1·4	4·0	−0·5	1·3	.....	·012	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
97	Boss 441	λ Arietis	01 52·4	23 07′	4·8	A6	·093	− 2·6	1·5 0·9	1·7 2·4	..... 0·3
98	Boss 446	A Cassiop.	01 53·8	70 25	4·6	A3	·062	+ 3·7	2·9 3·2	3·9 4·4	4·3 3·4
99	Boss 468	γ Androm.	01 57·8	41 51	2·3	K0	·073	−10·5	−1·8 −1·4	....	....
100	Boss 475	54 Cassiop.	02 00·4	71 05	6·7	G1	·389	+ 4·5	3·8 3·8	5·4 5·1	7·0 5·5
101	Boss 477	α Arietis	02 01·5	22 59	2·2	K2	·242	−18·5	0·9 3·8	3·5 2·6	....
102	Boss 482	β Triang.	02 03·6	34 31	3·6†	A6	·160	− 3·6	1·5 1·8	2·8 2·1	3·5 2·8
103	Boss 495	64 Ceti	02 06·1	08 06	5·7	G0	·173	−26·7	1·8 2·3	3·9 3·6	5·1 2·6
104*	Boss 497 (br.)	.....	02 06·6	29 50	6·2†	G0	·088	−22·2	2·1 1·5	2·1 1·2	0·2 1·6
105*	Boss 497 (ft.)	ι Triang.	02 06·6	29 50	7·2†	F4	·088	−22·8	3·6 3·8	2·8 3·8	3·5 3·8
106	Boss 499	60 Androm.	02 06·9	43 45	5·1	K5	·017	−43·6	−1·9 1·3	....	....
107	Boss 500	6 Persei	02 07·0	50 36	5·4	G7	·387	+15·1	2·0 2·7	0·4 0·7	....
108	H.R. 647	Bu. 1144	02 07·6	47 02	6·4†	F4	·099	−11·0	3·7 3·8	3·6 5·0	3·7 4·0
109	H.R. 653	.....	02 09·5	47 21	6·4	G9	.....	.....	2·1 1·4	1·5 1·4	....
110	Boss 510	.....	02 10·0	25 17	5·8	F3	·197	+20·8	4·1 3·6	3·1 3·0	3·9 3·4
111	Boss 514	δ Triang.	02 10·8	33 46	5·1	G1	1·180	− 6·2	4·0 4·0	4·9 4·6	4·6 4·0
112	Boss 523	Lal. 4268	02 12·8	01 17	5·8	F8	·527	+11·9	2·8 4·4	4·5 3·5	4·3 5·6
113	H.R. 690	.....	02 16·9	54 55	6·5	G5	.....	.....	−4·5 −3·2	−4·5 −1·8	..... −3·4
114	Boss 545	65 Androm.	02 18·9	49 50	4·9	K7	·032	− 1·7	−0·2 −0·2	..... −0·4	....
115	Boss 555	.....	02 21·5	31 22	5·8	K2	·046	−43·7	1·5 1·4	0·2 1·4	....
116	Boss 559	12 Triang.	02 22·3	29 14	5·4	F2	·091	−31·6	−0·8 −0·2	−0·7 1·8	−1·2 −0·5
117	Boss 561	13 Triang.	02 23·0	29 29	5·9	F9	·098	+36·7	4·8 4·6	3·3 4·1	4·9 4·8
118	Boss 565	.....	02 24·8	24 48	5·9	F4	·109	−17·8	3·1 2·3	4·3 3·1	2·7 2·5
119	Boss 582	15 Triang.	02 29·7	34 15	5·6	M3	·062	−15·3	....	..... −0·6	....
120	Boss 588	Pi II 123	02 30·6	06 25	5·9	K7	2·321	+13·1	7·0 4·4	6·9	....

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
97	.....	.....	0·8	.....	.....	.....	.....	.....	.....	.....	.....	**1·3**			
	.....	.....	1·8	2·2:	.....	.....	.....	.....	.....	.....	.....	**1·3**	.....	**·020**	·026
98	.....	.....	2·3	.....	.....	.....	.....	.....	.....	.....	.....	**3·3**			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**3·7**	.....	**·060**	
99	0·2	−0·4	.....	−0·2	−1·0	1·3	−1·4	−1·6	−1·9	−0·2	.....	**−0·7**			
	.....	0·0	1·8	−0·6	1·1	0·8	1·4	−0·7	−0·8	−1·7	1·0	**0·1**	−0·1	**·030**	·010
100	6·2	.....	3·8	5·9	4·4	.....	.....	.....	.....	.....	.....	**5·2**			
	5·9	.....	3·8	2·9	2·7	.....	.....	.....	.....	.....	.....	**4·3**	.....	**·041**	
101	−0·5	1·6	.....	0·0	2·5	0·2	0·3	0·4	0·5	1·1	.....	**1·0**			
	0·9	0·5	.....	2·1	1·7	0·0	1·3	1·3	0·4	1·3	0·4	**1·4**	0·7	**·063**	·044
102	.....	.....	0·1	.....	.....	.....	.....	.....	.....	.....	.....	**2·0**			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**2·2**	.....	**·050**	·020
103	1·3	.....	4·4	2·9	−0·7	.....	.....	.....	.....	.....	.....	**2·7**			
	2·1	4·6	4·6	1·8	0·2	.....	.....	.....	.....	.....	.....	**2·7**	.....	**·025**	
104	.....	.....	3·6	3·8	3·6	.....	.....	.....	.....	.....	.....	**2·6**			
	3·8	4·4	1·2	−0·4	2·0	.....	.....	.....	.....	.....	.....	**1·9**	.....	**·016**	
105	.....	.....	3·8	4·0	3·2	.....	.....	.....	.....	.....	.....	**3·5**			
	.....	.....	2·0	1·5	3·0	.....	.....	.....	.....	.....	.....	**3·0**	.....	**·016**	
106	−0·2	−0·7	.....	−0·8	.....	−1·5	−0·3	−0·2	−1·5	−0·8	.....	**−0·9**			
	1·0	−0·6	−1·4	−0·5	−0·9:	−0·2	0·3	0·9	−1·5	−0·3	0·4	**−0·1**	.....	**·008**	
107	0·8	0·9	0·4	−0·8	3·8	2·3	0·7	0·9	0·4	0·7	.....	**1·0**			
	1·0	.....	−1·1	0·4	.....	1·5	0·5	1·8	.....	.....	.....	**0·9**	0·7	**·013**	·006
108	.....	.....	4·2	5·2	2·8	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	4·0	4·3	2·0	.....	.....	.....	.....	.....	.....	**3·8**	3·4	**·031**	·075
109	1·5	2·3	0·7	0·8	1·7	1·5	0·9	0·6	0·2	1·7	.....	**1·3**			
	1·3	1·7	2·0	0·8	1·8	2·3	2·9	.....	.....	2·6	.....	**1·8**	.....	**·011**	
110	3·0	.....	5·2	3·9	2·5	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	3·4	2·6	2·5	.....	.....	.....	.....	.....	.....	**3·1**	.....	**·033**	
111	6·0	.....	3·1	5·2	2·9	.....	.....	.....	.....	.....	.....	**4·4**			
	5·6	.....	4·0	4·1	2·4	.....	.....	.....	.....	.....	.....	**4·1**	4·8	**·068**	·101
112	4·4	.....	.....	4·5	4·5	.....	.....	.....	.....	.....	.....	**4·2**			
	3·8	.....	3·9	3·4	4·8	.....	.....	.....	.....	.....	.....	**4·2**	3·6	**·048**	·024
113	.....	−2·8	−4·5	−2·0	−4·0	−1·2	.....	.....	−3·4	−1·7	.....	**−3·2**			
	−4·1	−3·0	−3·0	−4·0	−6·0	−3·5	−6·0:	−4·8:	.....	.....	.....	**−4·1**	.....	**·001**	
114	1·8	0·3	.....	−0·8	.....	−0·9	1·2	2·2	0·9	−0·5	.....	**0·4**			
	−0·2	.....	0·2	0·1	0·4	0·3	0·8	1·7	0·9	0·4	0·0	**0·3**	0·3	**·012**	·005
115	−0·1	0·0	3·2	1·4	2·0	0·2	0·0	0·5	0·1	1·3	.....	**0·9**			
	0·2	1·1	0·0	−1·0	0·1	0·6	−0·3	2·5	2·3	1·7	0·8	**0·8**	.....	**·010**	
116	.....	.....	0·1	.....	0·9	.....	.....	.....	.....	.....	.....	**−0·3**			
	.....	.....	−1·7	−2·4	0·5	.....	.....	.....	.....	.....	.....	**−0·4**	.....	**·007**	
117	3·6	.....	6·5	5·7	4·2	.....	.....	.....	.....	.....	.....	**4·7**			
	4·4	.....	4·0	2·6	4·6	.....	.....	.....	.....	.....	.....	**4·2**	.....	**·052**	
118	.....	.....	5·3	4·3	1·6	.....	.....	.....	.....	.....	.....	**3·6**			
	.....	.....	2·6	1·9	2·5	.....	.....	.....	.....	.....	.....	**2·5**	.....	**·027**	
119	.....	.....	.....	−0·6	.....	−2·0	−0·2	−0·5	0·2	−1·1	0·0	**−0·6**			
	.....	−0·4	−0·6	−0·3	.....	−1·7	−0·6	−0·1	−1·2	−0·9	−0·3	**−0·7**	0·3	**·006**	·015
120	6·7	7·5	.....	6·6	.....	.....	.....	.....	6·7	6·3	.....	**6·8**			
	6·4	6·6	7·4	7·4	7·2	7·5	6·8	6·7	7·0	6·8	6·5	**6·7**	6·5	**·147**	·131

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
121	H.R. 761	.....	02 31·1	32 27′	6·3	F6	.....	.....	2·7 3·9	2·6 1·4	3·9 3·5
122	H.R. 766	.....	02 31·3	07 18	6·0	K0	.....	.....	2·2 1·9	1·1 2·6	....
123	H.R. 768	.....	02 32·1	37 19	6·3	F6	.....	.....	0·6 1·2	3·6 4·7	2·1 3·4
124	Boss 607	.....	02 35·0	05 41	6·2	F4	·053	+ 7·0	3·3 2·8	4·0 4·1	3·6 3·5
125	Boss 617	η Persei	02 37·4	48 48	4·2	F8	·352	+26·3	3·2 4·2	4·0 4·2	4·4 4·8
126	Boss 619	14 Persei	02 37·5	43 52	5·6	G1	·006	− 4·7	−3·2 −2·6	−4·2 −3·6	−3·2 −2·8
127	Boss 624	36 Arietis	02 38·7	17 21	6·5	K0	·072	−40·2	....	..... 1·4	....
128	Boss 634	39 Arietis	02 42·0	28 50	4·6	K0	·199	−19·3	2·5 1·9	0·7 2·4	....
129	Boss 635	.....	02 42·9	17 52	6·0	K2	·054	+38·8	−0·5 −0·8	2·1	....
130	Boss 637	SU Cassiop.	02 43·0	68 28	6·1	F4	·017	+0·7	0·1 −0·1	0·8 0·4	−1·2 −0·4
131	H.R. 831	.....	02 43·2	36 54	6·4	F3	.....	.....	0·3 2·0	0·6 1·8	2·2 1·9
132	Boss 639	η Persei	02 43·4	55 29	3·9	K4	·029	+ 2·3	−1·8	....	....
133	Boss 646	17 Persei	02 45·4	34 39	4·7	K4	·079	+10·5	....	....	....
134	Boss 653	τ Persei	02 47·2	52 21	4·1	G1	·010	+ 3·9	2·8 2·0	1·1 0·6	4·0 4·3
135	Boss 654	20 Persei A	02 47·4	37 56	5·8†	F2	·102	− 2·4	3·7 2·2	1·8 3·6	0·7 2·2
136	Boss 656	.....	02 48·0	61 07	5·6	F4	·174	+31·6	5·0 4·0	3·2 3·9	6·0 4·7
137	H.R. 865	.....	02 49·8	46 45	6·1	K3	.....	.....	....	....	....
138	Boss 660	45 Arietis	02 50·2	17 55	5·9	M8	·019	+38·4	−2·4 −3·0	....	....
139	Boss 662	.....	02 50·9	07 59	6·1	F7	·116	+17·5	6·0 3·9	4·3 3·5	2·9 2·6
140	Boss 667	47 Arietis	02 52·3	20 16	5·8	F2	·223	+19·6	4·1 3·4	2·6 3·0	3·9 2·3
141	Boss 669	.....	02 52·8	79 01	5·7	M1	·039	−32·4	....	..... 0·4	....
142	Boss 670	24 Persei	02 52·9	34 47	5·0	K4	·061	−39·6	..... 1·4	....	....
143	Boss 672	Groom. 590	02 53·1	46 49	5·6	G5	·035	+ 4·3	0·2 1·1	2·7 1·8	0·8 0·9
144	.....	Lal. 5490	02 55·9	61 21	6·7	G3	1·004	− 4·0	5·5 4·3	6·0 5·8	3·6 2·6

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
121	5·3	.....	2·0	4·1	2·8	.....	.....	.....	.....	.....	.....	3·3			
	4·2	.....	1·2	2·2	1·1	.....	.....	.....	.....	.....	.....	2·5	.....	·021	
122	0·3	3·2	1·7	−0·8	−0·7	0·4	−0·2	0·6	−0·7	0·7	.....	0·6			
	1·2	1·6	0·6	−0·8	0·8	2·0	−0·3	2·0	0·6	2·5	.....	1·2	.....	·010	
123	3·3	.....	0·5	2·5	0·8	.....	.....	.....	.....	.....	.....	1·9			
	4·7	.....	−0·2	1·2	2·0	.....	.....	.....	.....	.....	.....	2·4	.....	·015	
124	.....	.....	4·0	3·1	3·6	.....	.....	.....	.....	.....	.....	3·6			
	.....	.....	3·2	2·5	4·0	.....	.....	.....	.....	.....	.....	3·4	.....	·029	
125	1·9	.....	5·1	4·9	4·3	.....	.....	.....	.....	.....	.....	4·0			
	.....	.....	5·2	4·5	3·8	.....	.....	.....	.....	.....	.....	4·4	3·9	·100	·083
126	.....	.....	−1·7	−3·0	−3·4	.....	.....	.....	.....	.....	.....	−3·1			
	−1·8	2·8	−1·2	−3·2	−2·9	−3·8	.....	.....	.....	.....	.....	−2·8	−2·6	·002	
127	1·9	1·2	0·4	0·7	1·7	−1·7	.....	−0·2	.....	1·4	.....	0·6			
	1·3	0·0	−0·2	−2·0	.....	−1·0	1·4	−0·1	−0·7	0·5	−0·7	0·0	.....	·006	
128	0·6	1·7	.....	−0·4	2·8	0·5	2·1	1·8	1·2	2·3	.....	1·4			
	−0·4	1·0	3·4	0·8	2·0	−0·2	0·8	−0·3	1·4	1·3	0·8	1·2	0·0	·022	·027
129	0·0	0·0	1·5	−1·3	−2·5	0·0	0·3	−0·4	−1·2	0·5	.....	−0·1			
	.....	.....	−2·0	−0·7	−0·3	2·0	0·3	1·3	−0·3	−0·2	−1·1	−0·2	.....	·006	
130	.....	.....	2·1	1·0	−0·8	.....	.....	.....	.....	.....	.....	0·3			
	.....	.....	0·6	−0·5	0·2	.....	.....	.....	.....	.....	.....	0·0	−1·4	·006	·010
131	.....	.....	2·5	3·4	1·5	.....	.....	.....	.....	.....	.....	1·8			
	.....	.....	2·2	1·6	2·1	.....	.....	.....	.....	.....	.....	1·9	.....	·012	
132	−1·2	0·5	.....	−2·8	.....	−2·4	−2·0	−3·4	−2·0	−1·0	.....	−1·8			
	0·1	−2·4	−3·4	−2·3	.....	−0·6	−1·0	−3·5	−3·0	−0·6	−0·7	−1·7	0·4	·007	
133	0·8	−0·6	.....	−0·6	.....	−2·2	−2·5	−0·3	−0·7	−2·4	.....	−1·0			
	.....	.....	−2·5	0·2	−2·3	−2·3	.....	−0·3	0·2	−1·2	−0·9	−1·2	0·7	·007	·010
134	1·0	.....	2·1	2·3	3·9	.....	.....	.....	.....	.....	.....	2·5			
	2·2	4·3	2·4	−1·3	4·7	.....	.....	.....	.....	.....	.....	2·4	−0·2	·047	
135	.....	.....	2·5	1·6	0·9	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	2·5	2·7	1·2	.....	.....	.....	.....	.....	.....	2·4	2·5	·019	·013
136	.....	.....	1·9	5·8	3·5	.....	.....	.....	.....	.....	.....	4·2			
	.....	.....	2·6	3·9	3·9	.....	.....	.....	.....	.....	.....	3·8	.....	·048	
137	0·8	−1·2	.....	−2·6	−0·7	−2·2	−0·1	−2·8	−2·9	−0·5	.....	−1·4			
	.....	−1·9	.....	.....	.....	.....	0·2	−2·8	−2·4	0·2	−0·3	−1·2	.....	·003	
138	.....	.....	.....	−1·6	.....	−0·1	−2·9	−3·5	−2·0	−2·0	−2·0	−2·0			
	.....	−2·4	−1·8	−1·5	.....	−0·6	−2·5	−2·7	−2·0	−1·4	−1·2	−1·9	−0·3	·003	·011
139	4·3	.....	4·9	6·0	3·9	.....	.....	.....	.....	.....	.....	4·6			
	3·4	.....	3·6	3·4	3·5	.....	.....	.....	.....	.....	.....	3·4	.....	·038	
140	.....	.....	4·8	5·2	4·0	.....	.....	.....	.....	.....	.....	4·1			
	3·8	.....	3·3	4·0	3·6	.....	.....	.....	.....	.....	.....	3·4	3·3	·039	
141	.....	.....	.....	−0·6	.....	−1·5	0·1	0·4	−0·4	−0·7	−0·2	−0·4			
	−2·3	−0·8	.....	−1·2	.....	−1·0	−0·6	−0·1	−0·1	−0·8	−0·5	−0·7	.....	·006	
142	2·0	0·0	.....	−1·2	.....	−1·5	1·2	−0·5	−1·5	0·2	.....	−0·2			
	1·6	1·1	−1·4	−1·0	.....	−0·6	0·4	0·8	−1·3	0·4	−1·1	0·0	.....	·010	
143	3·1	.....	1·6	4·6	−0·1	.....	−0·3	−1·6	0·8	0·3	.....	1·1			
	0·6	.....	1·5	2·6	−2·7	−0·1	−0·2	−0·6	.....	.....	.....	0·5	0·5	·011	−·007
144	3·7	.....	2·7	4·0	4·2	.....	.....	.....	.....	.....	.....	4·2			
	3·0	.....	5·5	3·2	4·7	.....	...	...	.....	.....	.....	4·2	5·2	·032	·043

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
145	Boss 687	.....	02 56·2	81 05′	6·0	A4	·047	+ 4·6	2·4 2·7	4·5 4·1	4·4 2·2
146	Boss 689	.....	02 56·4	26 14	6·7	G5	·297	+ 1·7	4·9 4·7	5·8 5·2	....
147	Boss 691	α Ceti	02 57·1	03 42	2·8	M1	·080	−37·3	−1·8 −1·1	....	....
148*	Boss 694	γ Persei	02 57·6	53 07	3·6†	A+F7	·012	+ 2·7	1·4 2·1	−1·0 −0·2	..... 4·6
149	Boss 697	.....	02 58·0	56 19	5·1	G6	·069	−43·5	4·4 3·7	1·3 0·6	....
150	Boss 698	ρ Persei	02 58·8	38 27	3·7	M6	·175	+25·4	−1·6 −2·0	....	....
151	Boss 704	.....	03 00·9	12 48	5·8	G6	·072	−25·2	3·7 3·0	2·2 2·3	....
152	Boss 710	ι Persei	03 01·8	49 14	4·2	G1	1·269	+49·1	4·1 4·2	3·5 3·2	4·8 5·5
153	Boss 713	κ Persei	03 02·7	44 29	4·0	G8	·242	+28·3	2·1 3·3	1·8 1·9	....
154	H.R. 946	.....	03 04·6	26 31	6·1	K5	.....	.....	....	....	....
155	H.R. 949	.....	03 05·5	47 22	6·4	K8	.....	.....	....	....	....
156	H.R. 956	.....	03 06·4	47 50	6·0	K1	.....	.....	−0·6 0·2	2·7 2·5	....
157*	Boss 726	.....	03 08·6	84 33	6·3†	G4	·151	+37·4	−2·0 1·3	−1·0 −0·5	2·0 3·1
158	Boss 746	.....	03 12·5	33 51	4·9	K2	·016	− 1·7	0·9	0·0 0·8	....
159	Boss 755	.....	03 14·3	28 41	4·7	K9	·029	− 7·8	0·0 1·8	....	....
160	Boss 758	.....	03 14·7	48 43	6·2	F5	·210	+22·8	3·9 3·6	2·5 3·1	3·7 3·5
161	Boss 770	63 Arietis	03 17·0	20 23	5·2	K3	·048	− 5·2	0·9 1·0	..... 1·7	....
162	Boss 772	α Persei	03 17·2	49 30	1·9	F4	·041	− 3·2	−0·9 −0·1	1·7	−2·1 0·4
163	Boss 775	64 Arietis	03 18·4	24 22	5·7	K4	·061	+ 3·8	....	....	....
164	Boss 778	ο Tauri	03 19·4	08 41	3·8	G5	·102	−31·5	−0·6 0·4	−1·2 −0·2	....
165	Boss 792	66 Arietis	03 22·6	22 28	6·1	G8	·114	+42·3	4·9 2·8	2·8 2·8	....
166	Boss 795	σ Persei	03 23·5	47 39	4·6	K4	·021	+15·1	1·6 1·6	..... 0·8	....
167	Boss 804	.....	03 25·4	12 36	4·3	G9	·021	+ 4·9	1·6 0·9	1·3 1·0	....
168	Boss 814	ε Eridani	03 28·2	−09 48	3·8	K1	·967	+ 0·5	5·8 6·7	6·2 6·9	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
145	.....	.....	3·9	1·7	2·6	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	2·7	2·2	2·0	.....	.....	.....	.....	.....	.....	**2·7**	.....	**·025**	
146	4·9	3·7	3·3	5·1	3·8	.....	.....	.....	.....	.....	.....	**4·5**			
	5·0	.....	2·4	2·6	2·1	4·5	.....	.....	.....	.....	.....	**3·8**	.....	**·031**	
147	.....	.....	.....	0·3	.....	−0·2	0·2	−0·7	−0·5	−1·0	0·8	**−0·3**			
	.....	−1·2	0·2	1·1	.....	−0·2	0·4	−0·1	−1·0	−1·1	0·3	**−0·3**	−0·1	**·024**	·013
148	.....	.....	0·3	−1·3	1·8	.....	.....	.....	.....	.....	.....	**0·2**			
	.....	.....	1·8	−0·4	3·5	.....	.....	.....	.....	.....	.....	**1·9**	−0·1	**·031**	·011
149	.....	2·1	3·5	2·8	2·9	.....	.....	.....	.....	.....	.....	**2·8**			
	0·8	0·6	3·6	1·2	3·4	4·0	0·5	.....	.....	0·7	.....	**1·9**	.....	**·028**	
150	.....	.....	.....	−2·2	.....	−1·0	−2·0	−1·2	−2·1	−1·4	−2·5	**−1·7**			
	.....	−1·7	−2·4	−1·1	.....	−1·9	−4·6	−2·7	−2·8	−1·2	−3·0	**−2·3**	−0·8	**·007**	·048
151	.....	0·5	2·3	2·2	1·8	.....	.....	.....	.....	.....	.....	**2·1**			
	0·6	−0·1	3·0	−0·6	0·0	1·4	.....	2·0	.....	1·3	.....	**1·3**	.....	**·015**	
152	5·0	.....	4·0	5·1	3·3	.....	.....	.....	.....	.....	.....	**4·3**			
	4·2	.....	3·6	5·4	3·6	.....	.....	.....	.....	.....	.....	**4·3**	4·4	**·105**	·104
153	2·0	1·0	2·6	4·3	2·0	2·3	1·1	1·5	.....	.....	.....	**2·1**			
	0·9	0·1	4·0	3·8	.....	1·5	0·9	0·6	.....	.....	.....	**1·9**	0·9	**·040**	·037
154	1·3	0·0	.....	−1·2	.....	−2·1	0·5	0·7	−0·9	0·4	.....	**−0·2**			
	−0·6	.....	−2·3	−0·7	−1·7	−1·7	−1·5	0·4	−1·2	0·6	−1·2	**−1·0**	.....	**·005**	
155	.....	.....	.....	.....	.....	.....	−0·3	0·8	1·1	0·5	.....	**0·5** :			
	0·1	−0·5	.....	.....	.....	.....	0·8	1·4	−0·3	1·0	0·9	**0·5** :	.....	**·007**	
156	1·6	1·5	0·7	−0·4	−0·7	0·4	1·7	1·6	0·0	2·0	.....	**0·9**			
	2·5	0·8	0·6	−0·5	0·4	2·1	1·9	2·2	0·2	0·9	−0·8	**1·0**	.....	**·010**	
157	.....	.....	−1·8	−4·0	1·7	.....	.....	.....	.....	.....	.....	**−0·8**			
	0·3	.....	−0·9	−3·6	.....	−2·8	.....	.....	.....	.....	.....	**−0·6**	.....	**·004**	
158	−0·2	−0·9	−2·5	−1·8	+2·2	−2·0	−1·0	−2·4	−1·9	−1·3	.....	**−0·9**			
	−0·9	−0·2	−1·6	−1·0	1·4	−2·0	0·6	−2·4	−0·5	−1·7	0·2	**−0·6**	0·2	**·007**	·012
159	1·3	0·3	.....	−0·6	.....	−1·2	1·0	1·1	0·0	0·2	.....	**0·2**			
	0·0	−0·5	−0·2	−0·4	0·6	1·5	0·8	0·0	−0·8	0·6	0·3	**0·2**	0·3	**·012**	
160	.....	.....	5·2	4·2	4·0	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	3·4	3·1	4·2	.....	.....	.....	.....	.....	.....	**3·5**	.....	**·032**	
161	0·6	0·0	3·7	0·0	−1·5	3·7	0·4	−0·5	−1·3	2·5	.....	**0·8**			
	2·0	0·6	−2·0	−1·0	−0·9	0·8	1·3	0·3	−0·1	1·9	0·8	**0·5**	0·4	**·012**	
162	.....	.....	−0·6	−1·0	−1·1	.....	.....	.....	.....	.....	.....	**−0·7**			
	.....	.....	0·6	−1·7	−1·8	.....	.....	.....	.....	.....	.....	**−0·5**	−1·3	**·031**	·017
163	1·8	0·5	.....	−1·5	.....	−1·3	1·2	2·2	1·4	0·8	.....	**0·6**			
	1·6	0·6	−2·3	−1·0	.....	−0·6	1·5	2·4	2·4	2·2	0·6	**0·7**	.....	**·010**	
164	2·7	.....	0·2	1·6	0·4	0·7	.....	.....	.....	.....	.....	**0·6**			
	−0·5	0·0	1·8	1·3	.....	1·0	−0·1	1·1	.....	.....	.....	**0·5**	0·1	**·022**	·006
165	2·0	2·3	1·0	2·7	1·4	.....	.....	.....	.....	.....	.....	**2·4**			
	2·4	2·3	−0·1	−0·6	0·5	0·4	.....	.....	.....	.....	.....	**1·3**	.....	**·014**	
166	0·2	−0·5	.....	−0·1	.....	1·0	−2·5	−1·0	0·5	−1·0	.....	**−0·2**			
	0·5	−1·3	−1·4	0·1	−1·5	0·6	−2·0	−0·9	0·9	−1·6	−0·7	**−0·4**	0·4	**·010**	·013
167	1·6	1·2	3·2	0·7	4·2	0·8	0·8	1·0	0·8	1·3	.....	**1·5**			
	0·2	0·1	1·9	1·3	3·4	2·4	.....	.....	.....	2·0	.....	**1·4**	0·1	**·027**	
168	6·3	5·4	7·2	8·2	4·1	.....	6·2	5·7	6·4	6·3	.....	**6·2**			
	6·3	6·2	6·4	7·0	6·4	5·7	5·1	6·4	5·8	6·2	5·8	**6·2**	6·0	**·302**	·317

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
169	Boss 825	.....	03 31·8	00 05′	4·4	F9	·536	+14·9	4·7 4·9	3·5 4·1	4·6 4·2
170	Boss 826	.....	03 33·5	62 54	5·3	M5	·020	−24·4	−0·9 −0·6	....	....
171	Boss 835	.....	03 34·7	02 44	5·8	G5	·033	+ 7·6	....	3·6 3·0	....
172	Boss 840	.....	03 36·5	66 53	5·8	F3	·141	+ 8·3	0·4 1·2	0·6 2·2	1·1 1·0
173	H.R. 1127	.....	03 36·9	48 13	6·3	K4:	.....	.....	....	....	....
174	Boss 843	14 Tauri	03 38·0	19 21	6·3	G8	·139	+66·3	1·7 0·9	2·1 2·2	....
175	Boss 847	ν Persei	03 38·4	42 16	3·9	F3	·007	−16·1	−0·6 −0·8	2·0 1·6	+0·1 −0·4
176	Boss 848	δ Eridani	03 38·5	−10 06	3·7	G9	·746	−21·1	6·2 4·6	3·6 3·8	....
177	Boss 850	.....	03 38·8	70 34	6·1†	A2	·070	+20·1	−0·7 0·4	0·3 1·2	3·8 2·3
178	H.R. 1159	.....	03 40·8	06 30	6·1	K1	.....	.....	0·8	.....	.....
179	Boss 900	A Persei	03 49·2	50 24	6·2†	F4	·164	+20·5	3·3 3·9	1·2 2·0	4·3 4·0
180	Boss 908	32 Tauri	03 50·9	22 12	5·8	F3	·133	+22·8	1·5 1·4	3·4 3·7	1·7 1·6
181	Boss 924	.....	03 56·1	58 53	5·1	F3	·006	−19·0	−0·4 −0·1	0·7 1·6	−0·6 0·5
182	Boss 933	36 Tauri	03 58·4	23 50	5·7	F4	·023	+ 8·7	3·4 3·3	1·5 1·7	3·1 3·7
183	Boss 936	37 Tauri	03 58·8	21 49	4·5	K0	·116	− 0·8	1·0 1·3	0·7 1·9	....
184	Boss 937	.....	03 58·9	02 33	5·4	F6	·193	−33·2	4·7 3·5	2·8 3·2	4·6 3·0
185	Boss 944	.....	04 00·8	28 44	5·3	F2	·080	+ 1·9	1·9 2·6	2·1 3·3	2·3 2·4
186	Boss 950	50 Persei	04 01·9	37 47	5·6	F8	·261	−14·8	3·6 4·6	4·3 4·9	4·2 5·2
187	Boss 952	43 Tauri	04 03·3	19 21	5·7	K1	·117	+10·6	0·7 1·9	..... 1·6	....
188	Boss 961	.....	04 06·0	05 16	5·7	F4	·144	.....	2·8 2·3	2·8 3·1	2·1 1·4
189	H.R. 1295	.....	04 06·8	17 02	6·3	K0	.....	.....	.....	.....	.....
190	Boss 971	.....	04 08·2	07 28	5·4	F0	·003	−14·8	3·0 2·2	3·8 4·2	3·2 2·2
191	Boss 973	.....	04 08·8	57 37	5·8	K0	·054	−37·4	3·7 2·0	1·3 2·8	....
192	Boss 984	40 Eridani	04 10·7	−07 49	4·5	K1	4·082	−58·2	6·0 6·0	6·7 6·0	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
169	3·5	.....	2·5	5·2	5·3	.....	.....	.....	.....	.....	.....	**4·1**			
	2·8	.....	2·3	4·4	4·4	.....	.....	.....	.....	.....	.....	**3·9**	3·6	·083	·058
170	.....	.....	.....	−1·9	.....	0·0	0·4	0·4	−1·4	−1·4	−0·2	**−0·6**			
	.....	−2·2	−2·3	−1·6	.....	−1·0	−1·9	0·7	−0·2	−1·8	−1·2	**−1·2**	−0·5	·006	
171	2·1	4·2	1·5	1·4	0·4	−0·4	.....	.....	.....	.....	.....	**1·8**			
	2·2	3·2	1·5	.....	0·8	0·2	.....	2·0	0·4	−0·6	.....	**1·4**	.....	·014	
172	.....	.....	1·8	0·8	0·7	.....	.....	.....	.....	.....	.....	**0·9**			
	.....	.....	0·9	1·3	1·0	.....	.....	.....	.....	.....	.....	**1·3**	.....	·012	
173	.....	.....	.....	.....	.....	.....	−2·5	−0·2	−0·9	−0·8	.....	**−1·1**			
	−0·8	−1·3	.....	.....	.....	.....	−1·4	−2·4	−1·2	0·1	−0·1	**−1·0**	.....	·003	
174	0·0	2·0	0·1	−0·4	−1·3	0·5	1·2	.....	.....	−0·5	.....	**0·5**			
	0·9	1·6	−0·4	−0·6	−1·2	−0·8	0·8	.....	.....	0·4	.....	**0·5**	.....	·007	
175	.....	.....	1·5	−2·1	−1·7	.....	.....	.....	.....	.....	.....	**−0·1**			
	.....	.....	1·1	−0·4	−0·6	.....	.....	.....	.....	.....	.....	**0·1**	0·6	·016	·021
176	4·8	3·6	6·3	4·1	4·2	.....	.....	.....	.....	.....	.....	**4·7**			
	4·4	3·9	5·3	4·8	2·9	5·6	3·8	5·7	5·2	3·5	.....	**4·5**	3·4	·151	·147
177	.....	.....	.....	.....	−0·6	.....	.....	.....	.....	.....	.....	**0·7**			
	.....	.....	3·2	−0·2	0·0	.....	.....	.....	.....	.....	.....	**1·2**	.....	·009	
178	2·3	3·4	0·8	0·6	−0·7	−0·2	2·1	2·0	0·3	0·8	.....	**1·1**	.....	·010	
179	.....	.....	2·8	3·8	3·2	.....	.....	.....	.....	.....	.....	**3·1**			
	.....	.....	3·3	3·0	4·2	.....	.....	.....	.....	.....	.....	**3·4**	.....	·026	
180	.....	.....	3·4	4·0	1·9	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	2·2	2·9	2·4	.....	.....	.....	.....	.....	.....	**2·4**	.....	·022	
181	.....	.....	0·1	−1·3	−1·4	.....	.....	.....	.....	.....	.....	**−0·5**			
	.....	.....	0·4	−1·4	−0·2	.....	.....	.....	.....	.....	.....	**0·1**	.....	·009	
182	.....	.....	4·9	−0·6	3·0	.....	.....	.....	.....	.....	.....	**2·5**			
	.....	.....	3·4	−0·2	3·4	.....	.....	.....	.....	.....	.....	**2·5**	3·5	·023	·014
183	0·5	1·5	3·2	0·4	1·5	2·9	−0·4	1·6	2·4	1·4	.....	**1·4**			
	1·2	0·1	2·5	0·8	2·8	1·8	0·8	1·9	−0·3	1·6	.....	**1·4**	0·8	·024	−·017
184	.....	.....	6·0	4·4	2·9	.....	.....	.....	.....	.....	.....	**4·2**			
	4·2	.....	3·2	3·2	4·0	.....	.....	.....	.....	.....	.....	**3·5**	3·2	·049	
185	.....	.....	1·8	4·0	3·3	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	−0·4	3·1	1·9	.....	.....	.....	.....	.....	.....	**2·1**	.....	·026	
186	4·4	.....	4·5	5·5	3·6	.....	.....	.....	.....	.....	.....	**4·3**			
	3·4	.....	4·2	4·7	4·4	.....	.....	.....	.....	.....	.....	**4·5**	3·9	·058	·048
187	1·2	0·9	2·6	0·6	0·8	1·6	0·2	1·5	0·4	0·8	.....	**1·0**			
	0·3	0·0	0·8	0·4	0·4	.....	1·4	1·4	0·9	1·3	.....	**0·9**	1·4	·011	·024
188	.....	.....	0·7	5·0	2·5	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	1·7	3·8	3·4	.....	.....	.....	.....	.....	.....	**2·6**	3·1	·024	
189	1·6	1·2	.....	.....	.....	.....	−1·9	1·0	2·4	0·5	.....	**0·8**	.....	·008	
190	.....	.....	2·3	.....	3·4	.....	.....	.....	.....	.....	.....	**3·1**			
	.....	.....	2·8	3·1	3·3	.....	.....	.....	.....	.....	.....	**3·0**	.....	·034	
191	1·2	0·7	1·3	2·5	3·8	3·2	1·1	1·2	2·4	3·0	.....	**2·1**			
	0·9	0·7	1·5	1·7	2·0	1·8	2·7	2·7	0·9	2·8	.....	**1·9**	.....	·017	
192	6·5	6·2	5·3	.....	6·8	.....	5·5	6·5	6·1	6·7	.....	**6·2**			
	6·2	6·4	5·4	5·7	4·4	6·2	6·7	7·0	6·4	6·2	5·8	**6·0**	6·2	·209	·196

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
193	Boss 989	ω Tauri	04 11·4	20 20′	4·8	A3	.....	.....	1·3 1·2	2·4 3·6	2·0 1·8
194	Boss 1000	γ Tauri	04 14·1	15 23	3·9	G6	·123	+26·1	0·4 2·6	1·4 0·9	....
195	Boss 1004	.....	04 14·3	13 48	5·6	F1*n*	·123	+37:	0·0 0·8	2·4 3·8	−0·8 1·0
196	Boss 1013	.....	04 16·4	13 50	5·8	A4	·121	+38:	0·4 1·2	0·4 2·0	3·7 2·2
197	Boss 1017	δ Tauri	04 17·2	17 18	3·9	G8	·118	+25·9	1·6 2·5	1·6 1·0	....
198	Boss 1021	56 Persei	04 18·1	33 44	5·8	F5	·094	−40·5	3·9 2·8	2·0 3·0	4·6 2·3
199	Boss 1040	.....	04 22·1	21 24	5·7	A5	·120	+35·7	0·4 1·1	1·2 1·9	−0·1 1·2
200	Boss 1042	.....	04 22·7	16 08	5·3	K1	·021	+ 5·5	2·7 2·8	2·6 2·4	....
201	Boss 1043	.....	04 22·7	14 30	6·0	F1*n*	·112	+50·1	1·5 2·4	3·0 3·4	−1·0 0·4
202	Boss 1044	ε Tauri	04 22·8	18 58	3·6	G8	·122	+27·3	1·4 1·7	0·5 1·4	....
203	Boss 1045	θ^1 Tauri	04 22·8	15 44	4·0	G6	·111	+25·1	1·8 2·4	1·9 1·3	....
204	Boss 1055	.....	04 24·9	15 29	5·5	A5	·113	+37·2	−1·2 0·2	2·1 2·7	2·7 1·1
205	Boss 1056	.....	04 25·0	13 31	5·5	F0	·112	+39·2	1·2 2·4	5·2 4·2	0·1 0·8
206	Boss 1060	.....	04 26·3	42 49	6·8	A9	·076	− 3·0	2·8 3·3	3·9 4·1	3·9 2·9
207	Boss 1061	.....	04 26·4	42 51	6·1	F1	·007	−25·8	1·4 1·5	2·0 2·3	1·5 2·2
208	Boss 1074	58 Persei	04 29·7	41 04	4·5	G1	·026	+ 5·1	−1·4 −1·3	−2·8 −2·0	0·5 −0·8
209	Boss 1077	α Tauri	04 30·2	16 19	1·1	K8	·205	+42·6	−0·2 0·8	....	....
210	H.R. 1489	.....	04 35·0	38 05	5·8	F9	.....	.....	3·1 3·5	3·7 3·2	5·3 5·8
211	Boss 1114	.....	04 38·9	10 58	5·4	A5	·100	+38·8	1·6 2·2	5·3 3·6	0·0 1·2
212	Boss 1117	4 Camelop.	04 39·7	56 35	5·4	A3	·158	− 4·6	0·2 −1·4	0·3 0·8	0·3 −0·4
213	Boss 1122	.....	04 40·5	11 31	5·4	A2	·068	+24·2	0·7 −0·1	2·2 2·6	2·5 2·4
214	Boss 1128	.....	04 42·7	63 20	5·8	M1	·112	−33·9	−0·3 −0·6	..... 0·2	....
215	Boss 1129	.....	04 42·8	31 16	5·8	K0	·116	+13·9	2·8 3·7	2·6 2·4	....
216	Boss 1140	π^3 Orionis	04 44·4	06 47	3·3	F5	·174	+ 9·6	4·1 4·4	3·1 3·0	5·0 5·2

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No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
193	.....	.....	3·7	.....	2·4	.....	.....	.....	.....	.....	.....	2·4			
	.....	.....	2·2	2·9	.....	.....	.....	.....	.....	.....	.....	2·3	.....	·032	
194	0·6	0·5	3·0	2·0	3·8	1·7	−1·7	1·1	1·2	2·0	.....	1·3			
	1·6	−0·1	3·8	2·9	.....	1·9	−0·6	.....	.....	0·7	.....	1·4	0·7	·031	
195	.....	.....	−0·1	.....	0·2	.....	.....	.....	.....	.....	.....	0·3			
	.....	.....	1·8	1·5	.....	.....	.....	.....	.....	.....	.....	1·8:	.....	·012	
196	.....	.....	.....	.....	−1·0	.....	.....	.....	.....	.....	.....	0·8			
	.....	.....	2·9	1·8	0·4	.....	.....	.....	.....	.....	.....	1·8	.....	·012	
197	1·4	1·0	3·3	2·5	0·8	1·2	1·6	1·2	0·8	2·2	.....	1·6			
	2·2	1·6	3·0	1·5	2·6	1·8	2·5	2·2	.....	2·7	.....	2·1	0·4	·039	·018
198	.....	.....	4·3	.....	3·2	.....	.....	.....	.....	.....	.....	3·6			
	.....	.....	3·8	4·1	2·2	.....	.....	.....	.....	.....	.....	3·0	.....	·032	
199	.....	.....	3·7	.....	0·7	.....	.....	.....	.....	.....	.....	1·2			
	.....	.....	2·4	1·3	.....	.....	.....	.....	.....	.....	.....	1·6	.....	·014	
200	2·3	1·8	3·1	1·8	3·8	1·2	0·3	0·8	0·0	1·2	.....	1·8			
	1·8	1·5	−0·6	0·4	1·6	1·6	2·4	.....	.....	1·3	.....	1·5	.....	·019	
201	.....	.....	1·5	.....	3·0	.....	.....	.....	.....	.....	.....	1·6			
	.....	.....	2·6	1·8	.....	.....	.....	.....	.....	.....	.....	2·1	.....	·015	
202	0·6	−0·5	2·3	3·7	2·2	3·2	3·0	1·8	2·4	3·6	.....	2·0			
	0·9	−1·1	3·3	2·9	3·0	2·7	1·1	0·9	3·1	3·5	.....	2·0	1·0	·048	·028
203	2·0	2·4	3·5	3·0	0·7	1·7	0·8	1·1	2·0	1·9	.....	1·9			
	3·2	1·1	3·1	2·0	2·8	1·9	0·4	2·0	1·7	1·5	.....	1·9	1·4	·038	·036
204	.....	.....	4·8	.....	1·3	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	2·8	2·0	1·1	.....	.....	.....	.....	.....	.....	1·6	1·6	·018	
205	.....	.....	1·5	.....	4·0	.....	.....	.....	.....	.....	.....	2·4			
	.....	.....	2·7	1·3	.....	.....	.....	.....	.....	.....	.....	2·3	.....	·023	
206	.....	.....	1·5	.....	3·2	.....	.....	.....	.....	.....	.....	3·1			
	.....	.....	2·4	1·8	2·5	.....	.....	.....	.....	.....	.....	2·8	.....	·017	
207	.....	.....	1·5	.....	3·2	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	2·1	2·1	1·7	.....	.....	.....	.....	.....	.....	2·0	.....	·015	
208	.....	.....	−0·5	−3·6	.....	.....	.....	.....	.....	.....	.....	−1·6			
	−0·7	.....	0·7	−2·8	.....	−2·0	−1·4	−2·7	.....	.....	.....	−1·4	−4·2:	·006	·027
209	1·6	−0·5	.....	0·7	.....	−0·8	1·0	2·3	1·0	−0·9	.....	0·5			
	0·2	−0·5	0·4	2·4	0·4	0·0	0·8	−0·2	0·6	0·2	.....	0·5	1·0	·076	·055
210	6·6	.....	3·3	5·3	4·0	.....	.....	.....	.....	.....	.....	4·5			
	6·0	.....	1·3	3·6	4·1	.....	.....	.....	.....	.....	.....	4·0	.....	·049	
211	.....	.....	2·3	.....	3·8	.....	.....	.....	.....	.....	.....	2·6			
	.....	.....	0·6	.....	2·5	.....	.....	.....	.....	.....	.....	2·0	.....	·024	
212	.....	.....	3·7	.....	0·6	.....	.....	.....	.....	.....	.....	1·0:			
	.....	.....	2·9	1·0	0·2	.....	.....	.....	.....	.....	.....	0·5:	.....	·012	
213	.....	.....	.....	.....	0·2	.....	.....	.....	.....	.....	.....	1·4			
	.....	.....	3·2	1·2	0·4	.....	.....	.....	.....	.....	.....	1·6	.....	·016	
214	.....	.....	.....	0·3	.....	0·9	−1·5	0·3	+0·9	0·4	−1·7	−0·3			
	.....	−0·7	0·3	1·8	.....	0·1	0·0	−0·5	−0·4	−0·3	−1·5	−0·2	0·5	·006	·001
215	0·9	0·9	2·4	1·1	1·3	1·6	0·8	.....	.....	.....	.....	1·6			
	0·4	1·6	0·6	0·8	1·7	1·4	3·0	.....	.....	2·6	.....	1·8	.....	·015	
216	.....	.....	4·4	5·0	3·7	.....	.....	.....	.....	.....	.....	4·2			
	.....	.....	1·7	2·8	4·8	.....	.....	.....	.....	.....	.....	3·7	.....	·135	·156

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
217	.....	Groom. 884	04 44·4	45 41	7·1	F9	·676	+21·7	·6·6 5·6	5·5 6·2	4·1 4·7
218	Boss 1166	.....	04 50·1	24 27	6·3	F2	·032	−22·9	1·5 2·3	2·1 3·0	2·4 1·0
219	Boss 1167	ι Aurigae	04 50·5	33 00	2·9	K4	·029	+10·1	−0·9 0·0	..... 0·0	....
220	Boss 1169	o^2 Orionis	04 50·7	13 21	4·3	K2	·098	−11·6	−0·3 2·4	1·0 1·2	....
221	Boss 1185	β Camelop.	04 54·5	60 18	4·2	G0	·014	− 1·4	−3·0 −4·0	−2·8 −1·9	−3·5 −3·6
222	Boss 1187	ε Aurigae	04 54·8	43 40	3·4	F2	·015	−13·3	−0·5 −0·4	−1·8 −1·5	−2·5 −1·5
223*	Boss 1190	ζ Aurigae	04 55·5	40 56	3·9	B+K4	·033	+ 8·	0·0 −1·1	2·7 3·0	....
224	Boss 1191	.....	04 56·3	85 50	6·5	F2	·068	+ 0·8	1·2 2·0	2·4 2·0	..... 0·9
225	.....	Lal. 9428	05 00·1	64 47	6·4	F4	·190	− 2·7	3·1 3·9	2·7 2·2	3·1 2·1
226	Boss 1212	104 Tauri	05 01·5	18 30	5·0	G3	·543	+ 6·0	1·9 2·4	3·9 3·4	3·7 3·1
227	Boss 1219	14 Orionis	05 02·5	08 22	5·9†	F1	·068	− 9·9	1·4 1·0	2·1 1·8	1·3 1·5
228	Boss 1222	.....	05 03·3	46 50	5·6	F3	·170	+26·2	1·9 2·6	1·4 3·2	2·1 1·6
229	H.R. 1670	.....	05 03·5	27 55	6·0	A8	.....	.....	0·4 2·6	2·1 2·0	..... 0·8
230	Boss 1240	ρ Orionis	05 08·1	02 45	4·6	K2	·015	+21·6	2·6 3·1	2·0 2·6	....
231	Boss 1244	14 Aurigae	05 08·8	32 35	5·1	A4	·013	−12·9	1·7 2·1	1·3 2·0	2·4 1·0
232	Boss 1246	α Aurigae	05 09·3	45 54	0·7†	G1	·438	+25·7	1·5 1·2	1·9 1·5	2·6 1·4
233	.....	16 Aurigae	05 11·6	33 17	4·8	K3	·190	−36·5	−0·3 1·3	0·8 0·8	....
234	Boss 1259	λ Aurigae	05 12·1	40 01	4·8	G1	·844	+58·9	4·9 4·8	4·6 4·9	5·6 3·4
235	Boss 1335	119 Tauri	05 26·3	18 32	4·7	M4	·015	+10·9	....	....	....
236	Boss 1347	α Leporis	05 28·3	−17 54	2·7	F4	·005	+ 5·2	−0·4 −1·6	+1·2 −1·2	−1·2 −0·3
237	Boss 1350	.....	05 28·7	47 40	6·0	F0	·030	+ 8·3	1·0 0·8	3·0 4·2	0·6 1·0
238	Boss 1367	22 Camelop.	05 30·6	56 18	6·9	F5	·139	+19·3	2·8 2·6	5·2 3·9	3·1 2·1
239	Boss 1373	40 Orionis	05 31·4	09 15	4·4	G7	·321	+83·3	3·1 2·4	1·7 2·3	....
240	Boss 1385	.....	05 33·2	53 26	6·4	K2	·510	− 2·2	7·0 6·0	5·8 5·7	....

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No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
217	4·2	.....	6·0	5·4	8·0	.....	.....	.....	.....	.....	.....	5·7			
	6·4	.....	4·8	5·8	7·5:	.....	.....	.....	.....	.....	.....	5·8	5·7	·054	·086
218	.....	.....	3·2	.....	3·3	.....	.....	.....	.....	.....	.....	2·5			
	.....	.....	1·7	2·4	3·6	.....	.....	.....	.....	.....	.....	2·3	.....	·016	
219	−0·2	0·0	.....	−0·5	.....	−0·3	−0·6	−1·6	−1·6	−1·0	.....	−0·7			
	0·6	−1·1	0·1	0·0	−0·8	−0·8	0·4	−0·9	−0·7	−1·2	0·4	−0·3	0·0	·021	−·011
220	1·2	.....	0·2	0·6	0·0	0·6	2·1	1·8	−0·9	0·4	.....	0·6			
	1·7	2·4	0·0	0·7	1·7	2·2	0·3	1·6	−1·2	0·4	−1·5	0·9	.....	·019	
221	.....	.....	−3·7	−1·4	−3·1	.....	.....	.....	.....	.....	.....	−2·9			
	−2·9	−2·6	−3·9	−2·0	−3·5	−2·5	.....	.....	.....	.....	.....	−3·0	−2·9	·004	
222	.....	.....	−5·0	−5·0	−2·6	.....	.....	.....	.....	.....	.....	−2·9			
	.....	.....	−3·5	−3·7	−3·0	.....	.....	.....	.....	.....	.....	−2·7	−2·0	·006	·060
223	1·8	0·5	0·4	0·7	3·3	.....	.....	.....	−1·3	−0·7	.....	0·8:			
	1·8	0·8	1·2	−1·2	−0·8	−0·6	.....	.....	.....	.....	.....	0·4:	1·6	.....	−·007
224	.....	.....	3·0	.....	1·2	.....	.....	.....	.....	.....	.....	2·0			
	.....	.....	2·6	0·2	2·0	.....	.....	.....	.....	.....	.....	1·9	.....	·012	
225	.....	.....	5·4	4·3	3·0	.....	.....	.....	.....	.....	.....	3·6			
	.....	.....	3·6	3·9	3·8	.....	.....	.....	.....	.....	.....	3·3	2·8	·026	·022
226	4·1	.....	0·7	3·5	3·0	.....	.....	.....	.....	.....	.....	3·0			
	2·2	2·4	2·0	4·2	4·7	.....	.....	.....	.....	.....	.....	3·0	4·4	·040	·045
227	.....	.....	5·0	1·7	0·2	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	4·1	1·7	0·2	.....	.....	.....	.....	.....	.....	1·7	2·0	·015	·022
228	.....	.....	2·2	2·3	0·3	.....	.....	.....	.....	.....	.....	1·7			
	.....	.....	2·2	3·7	2·1	.....	.....	.....	.....	.....	.....	2·6	2·3	·020	·032
229	.....	.....	5·2	3·0	0·9	.....	.....	.....	.....	.....	.....	2·3			
	.....	.....	2·2	2·0	1·1	.....	.....	.....	.....	.....	.....	1·8	.....	·016	
230	0·0	0·3	.....	0·8	0·8	1·0	2·7	2·3	2·4	4·3	.....	1·7			
	1·2	−0·3	−0·9	−1·0	−0·9	2·0	1·8	1·0	−0·8	2·8	1·9	1·0	.....	·022	
231	.....	.....	1·5	.....	1·1	.....	.....	.....	.....	.....	.....	1·6			
	.....	.....	2·0	1·7	1·4	.....	.....	.....	.....	.....	.....	1·7	.....	·020	
232	2·0	.....	1·3	0·6	−1·9	.....	.....	.....	.....	.....	.....	1·1:			
	2·6	.....	2·0	0·8	−1·4	0·9	.....	.....	.....	.....	.....	1·1:	0·1	·120	·067
233	−0·2	0·0	.....	−0·4	.....	.....	0·6	2·0	0·2	−0·7	.....	0·2			
	0·9	0·3	−1·2	0·5	0·6	2·1	0·8	.....	.....	0·3	0·0	0·6	.....	·013	
234	6·0	.....	4·4	5·2	5·3	.....	.....	.....	.....	.....	.....	5·2			
	3·1	.....	3·8	3·7	4·4	.....	.....	.....	.....	.....	.....	4·0	4·3	·091	·081
235	.....	.....	.....	−3·7	.....	−3·7	−3·4	−3·6	−3·0	−2·1	−2·3	−3·1			
	.....	−2·6	−5·1	−3·8	.....	−3·4	−2·2	−2·7	−3·0	−2·2	−2·6	−3·1	.....	·003	
236	.....	.....	−2·7	−4·5	−2·3	.....	.....	.....	.....	.....	.....	−1·7			
	.....	.....	−2·1	−2·1	−2·2	.....	.....	.....	.....	.....	.....	−1·6	−0·7	·013	·014
237	.....	.....	2·3	.....	0·8	.....	.....	.....	.....	.....	.....	1·5			
	.....	.....	1·0	1·9	1·2	.....	.....	.....	.....	.....	.....	1·7	.....	·013	
238	.....	.....	−0·6	.....	2·8	.....	.....	.....	.....	.....	.....	2·7			
	.....	.....	−0·2	3·1	3·4	.....	.....	.....	.....	.....	.....	2·5	.....	·014	
239	2·0	4·2	−0·5	1·5	2·8	2·0	.....	.....	.....	.....	.....	2·1			
	1·5	2·8	−0·6	0·1	1·9	1·5	0·9	1·2	.....	.....	.....	1·4	1·6	·030	·029
240	6·6	3·8	5·3	6·1	4·9	.....	.....	.....	5·2	5·3	.....	5·6			
	5·7	5·3	4·8	4·5	7·0	6·4	5·6	4·1	5·8	5·4	4·1	5·4	5·7	·066	·100

80600—5½

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
241	Boss 1415	.....	05 38·8	15 01	7·1	G8	·024	+33·7	−0·2 2·1	2·7 2·4	....
242	Boss 1429	τ Aurigae	05 42·3	39 09	4·6	G5	·034	−26·1	1·4 2·5	1·7 0·9	....
243	Boss 1434	132 Tauri	05 42·9	24 32	5·0	K0	·036	+ 5·9	1·8 1·4	3·1 2·2	....
244	Boss 1439	υ Aurigae	05 44·2	37 16	5·0	M1	·052	+32·5	−0·3 −0·8	..... −1·1	....
245	Boss 1442	ν Aurigae	05 44·6	39 07	4·2	K0	·007	+ 2·5	1·9 2·6	0·0 1·1:	....
246	Boss 1445	135 Tauri	05 44·7	14 16	5·7	K0	·036	+30·5	0·0 1·6	2·0 2·4	....
247	Boss 1456	δ Leporis	05 47·1	−20 54	3·9	K0	·697	+99·2	....	0·7 1·4	....
248	Boss 1461	χ Orionis	05 48·5	20 16	4·6	G1	·207	−25·9	2·7 4·1	5·3 5·0	3·2 4·0
249	Boss 1468	α Orionis	05 49·8	07 23	0·9	M1	·032	+ 5·5	−4·0 −4·2	..... −4·4	....
250	.....	Lal. 11196	05 50·3	13 56	6·5	G5	·629	−16·3	5·6 3·5:	..... 6·8	..... 7·3
251	Boss 1472	δ Aurigae	05 51·3	54 17	3·9	G6	·152	+ 6·8	2·2 4·2	0·8 1·6	....
252	Boss 1479	π Aurigae	05 52·5	45 56	4·6	M4	·012	− 3·5	−2·9 −4·2	....	....
253	Boss 1508	1 Gemin.	05 58·0	23 16	4·3	G4	·108	+ 7·7	2·1 2·8	1·8 2·4	0·8 0·4
254	.....	Lal. 11471	05 59·4	35 24	6·1	G1	·332	−22·0	4·9 3·9	4·9 5·0	4·2 3·1
255	Boss 1518	.....	06 00·7	23 39	6·9	K2	·019	−25·9	−2·1	0·2	....
256	Boss 1530	36 Camelop.	06 02·8	65 44	5·4	K1	·029	+10·0	2·4 0·8	1·4 2·0	....
257	Boss 1552	.....	06 06·7	60 02	5·6	K1	·047	+12·7	0·5 1·1	2·4 2·5	....
258	Boss 1557	.....	06 08·0	86 46	6·6	G4	·097	+33·8	....	..... 0·2	..... 0·1
259	Boss 1559	.....	06 08·6	17 57	5·7	A5	·030	+ 9·6	0·0 −0·1	1·4 1·8	2·4 1·5
260	Boss 1561	η Gemin.	06 08·8	22 32	3·7	M2	·062	+ 7·9	−0·9 −0·8	....	....
261	Boss 1563	.....	06 08·9	36 12	6·4	F4	·061	− 2·7	1·8 3·2	5·1 3·1	2·1 2·6
262	Boss 1564	71 Orionis	06 09·0	19 11	5·2	F7	·222	+20·6	4·1 4·0	3·7 3·4	3·4 2·1
263	Boss 1565	κ Aurigae	06 09·0	29 33	4·4	G9	·273	+10·2	1·1 0·8	1·7 2·1	....
264	Boss 1582	.....	06 11·9	05 08	5·8	G1	·281	− 5·6	2·4 3·3	4·7 4·4	3·9 3·1

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
241	0·0	.....	2·2	1·5	0·5	.....	.....	.....	.....	.....	.....	1·1:			
	1·4	1·0	0·0	−2·0	.....	.....	1·0	.....	.....	0·0	.....	0·9:	.....	·006	
242	.....	.....	0·5	1·2	0·8	0·9	−0·3	0·1	0·8	0·3	.....	0·7			
	1·0	1·4	0·9	1·3	2·1	0·5	0·0	0·6	1·5	0·4	.....	1·1	0·3	·018	·014
243	1·8	0·9	4·0	1·6	0·0	2·2	0·8	1·6	0·4	2·1	.....	1·7			
	0·7	−0·2	2·2	2·0	1·6	2·0	1·7	.....	.....	4·5	.....	1·8	2·3	·022	
244	.....	.....	.....	0·1	.....	−0·8	1·3	1·8	−0·1	0·1	−0·8	0·2			
	.....	−1·2	−1·3	0·4	.....	−0·8	0·6	1·2	−0·2	−0·4	−0·6	−0·4	0·0	·010	
245	−0·4	1·2	3·4	2·1	1·2	2·2	1·7	0·7	1·2	1·7	.....	1·4			
	0·4	0·5	1·5	2·7	.....	1·0	1·4	1·7	0·9	0·5	.....	1·3	0·2	·027	·022
246	2·6	0·8	2·0	1·2	0·0	1·6	1·3	1·0	0·5	2·0	.....	1·2			
	2·2	1·2	0·6	−0·2	0·5	2·0	3·4	.....	.....	2·8	0·4	1·5	.....	·013	
247	4·6	.....	0·7	−1·2	.....	0·6	.....	.....	.....	.....	.....	1·1:			
	4·2	.....	−1·6	0·8	.....	2·0	.....	.....	.....	.....	.....	1·4:	1·5	·030	
248	4·9	.....	4·2	5·5	4·1	.....	.....	.....	.....	.....	.....	4·3			
	5·0	.....	6·1	6·3	4·0	.....	.....	.....	.....	.....	.....	4·9	4·4	·100	·105
249	.....	.....	.....	−4·9	.....	−5·9	−3·7	−3·6	−4·1	−3·4	−4·4	−4·2			
	.....	−4·4	−4·6	−4·4	.....	−5·4	−3·7	−4·0	−4·9	−3·2	−4·4	−4·3	−3·8	·009	·021
250	7·3	4·9	.....	.....	4·5	.....	.....	.....	.....	.....	.....	5·6			
	6·8	5·6:	4·9	3·0	5·8	.....	.....	.....	.....	.....	.....	5·6	5·7	·066	·060
251	0·9	1·8	1·2	1·3	1·8	2·0	.....	.....	.....	.....	.....	1·5			
	1·4	1·4	3·1	3·8	1·0	1·5	1·2	1·2	.....	.....	.....	2·0	0·7	·037	·029
252	.....	.....	.....	−2·6	.....	−1·8	−2·9	−2·4	−2·3	−2·2	−2·3	−2·4			
	.....	−1·2:	−3·4	−1·2	.....	−1·3	−1·2	−1·0	−2·2	−2·1	−1·7	−2·0	−0·8	·004	
253	2·2	0·2	2·9	3·6	1·0	.....	.....	.....	.....	.....	.....	1·8			
	2·8	1·4	3·2	3·3	1·5	.....	.....	.....	.....	.....	.....	2·2	2·1	·034	·025
254	4·8	.....	4·3	4·1	5·9	.....	.....	.....	.....	.....	.....	4·7			
	4·0	.....	5·3	5·1	5·3	.....	.....	.....	.....	.....	.....	4·5	4·8	·050	·048
255	0·2	0·0	0·7	−0·1	0·0	0·5	−1·0	0·2	−0·9	−0·6	.....	−0·2			
	1·2	1·6	−0·9	−0·4	.....	2·0:	−0·6	.....	.....	−0·8	−1·1	0·0	.....	·004	
256	−0·2	0·0	0·9	−0·4	1·2	0·8	0·5	−2·0	−0·9	1·6	.....	0·4			
	0·4	−1·8	0·2	−1·0	1·1	1·9	0·2	0·0	0·6	2·2	0·3	0·6	.....	·010	
257	1·3	0·0	3·1	0·9	−0·2	1·6	0·0	0·7	−0·3	2·1	.....	1·0			
	0·9	−0·1	2·5	0·0	1·0	1·9	1·4	1·4	−0·3	−0·2	−0·6	0·9	.....	·012	
258	0·0	0·4	2·4	2·7	.....	.....	.....	−0·3	0·0	1·0	.....	0·9:			
	−0·1	1·0	1·5	−0·4	.....	.....	.....	.....	.....	1·2	.....	0·5:	.....	·007	
259	.....	.....	.....	.....	0·0	.....	.....	.....	.....	.....	.....	1·0			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·1	.....	·012	
260	.....	.....	.....	−2·0	.....	−2·0	−3·3	−2·5	−1·8	−1·6	−2·7	−2·1			
	.....	0·0	−2·1	−1·2	.....	−1·5	−2·1	−1·5	−2·1	−1·6	−1·9	−1·5	−0·5	·008	·016
261	.....	.....	4·0	.....	4·0	.....	.....	.....	.....	.....	.....	3·4			
	.....	.....	2·5	2·8	4·2	.....	.....	.....	.....	.....	.....	3·1	.....	·023	
262	4·8	.....	3·4	4·0	2·9	.....	.....	.....	.....	.....	.....	3·8			
	2·0	.....	4·4	4·2	4·2	.....	.....	.....	.....	.....	.....	3·5	2·9	·049	·039
263	1·4	0·0	−0·9	−1·8	1·3	−0·4	−0·2	−0·7	−0·3	−0·3	.....	0·1			
	0·8	1·6	−0·1	−0·6	1·8	−0·8	−0·3	0·2	0·7	1·1	.....	0·6	0·5	·016	·026
264	5·2	.....	3·4	1·0	2·9	.....	.....	.....	.....	.....	.....	3·4			
	4·1	.....	2·8	1·9	5·3	.....	.....	.....	.....	.....	.....	3·5	3·8	·034	·051

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
265	Boss 1583	.....	06 12·1	27 14	6·7	K1	·077	−56·8	.....	.....	.....
									.....	1·1	.....
266	Boss 1584	10 Gemin.	06 12·8	23 38	6·6	G4	·015	+29·1	−2·0	.....	.....
									−0·2	.....	−1·1
267	Boss 1585	3 Lyncis	06 12·9	61 48	7·2	F1	·103	+ 8·8	5·5	4·2	4·1
									5·2	5·6	3·3
268	.....	45 Aurigae	06 13·7	53 30	5·4	F5	·099	.....	1·3	1·1	1·9
									2·0	1·3	1·5
269	Boss 1604	μ Gemin.	06 16·9	22 34	3·2	M3	·130	+43·2	−1·0	.....	.....
									−1·4	.....	.....
270	Boss 1606	46 Aurigae	06 17·2	49 20	5·1	K2	·014	+ 6·3	−3·1	.....	.....
									−2·4:	.....	.....
271	Boss 1607	Groom. 1149	06 18·0	56 20	5·5	A3	·021	−14·9	0·0	0·9	1·6
									0·0	4·1	2·2
272	Boss 1626	77 Orionis	06 22·1	00 21	5·3	K0	·012	+16·3	0·9	1·0	.....
									2·2	1·4	.....
273	Boss 1627	6 Lyncis	06 22·1	58 14	6·0	G8	·331	+35·2	2·3	2·5	.....
									2·8	2·4	.....
274	Boss 1628	.....	06 22·1	02 58	5·8	G8	·043	+36·4	1·7	1·8	.....
									0·6	2·2	.....
275	Boss 1629	R.T. Aurigae	06 22·1	30 34	5·3	F8	·023	+11·6	−2·9	.....	−4·0
									−2·6	−2·9	−3·1
276	Boss 1643	.....	06 24·9	78 04	5·9	K5	·018	−7·7	−1·3	.....	.....
									0·6	0·3	.....
277	Boss 1650	.....	06 26·5	17 51	6·7	F7	·043	−16·3	1·5	1·4	3·6
									2·9	2·1	2·3
278	Boss 1665	8 Lyncis	06 28·6	61 34	6·0	G7	·342	−46·2	3·3	2·4	.....
									1·6	3·0	.....
279	Boss 1679	23 Gemin.	06 30·2	16 53	6·7	F5	·043	+17·1	3·9	4·9	4·5
									4·5	3·4	4·4
280	Boss 1694	50 Aurigae	06 32·2	42 35	5·1	K1	·061	+11·1	−1·5	0·7	.....
									0·8	2·1	.....
281	Boss 1717	ε Gemin.	06 37·8	25 14	3·2	G9	·020	− 1·7	−3·5	−2·0	.....
									−4·8	−0·8	.....
282	Boss 1720	.....	06 38·3	57 17	5·5	G6	·051	+18·1	2·5	3·1	.....
									3·0	2·1	.....
283	Boss 1722	28 Gemin.	06 38·4	29 04	5·5	K5	·029	+ 5·0	.....	.....	.....
									.....	.....	.....
284	Boss 1724	56 Aurigae	06 39·5	43 41	5·3	G0	·158	−29·7	3·5	4·0	3·8
									4·9	4·4	4·7
285	Boss 1725	ξ Gemin.	06 39·7	13 00	3·4	F5	·230	+12·6	−0·4	1·7	−1·3
									0·4	0·5	−0·5
286	Boss 1728	57 Aurigae	06 40·0	48 53	5·3	K0	·009	−13·6	0·4	1·1	.....
									1·3	1·4	.....
287	Boss 1753	.....	06 44·2	59 34	5·9†	A + F	·047	+13·7	1·5	−1·5	3·0
									2·1	0·2	4·0
288	Boss 1764	60 Aurigae	06 46·3	38 34	6·3	F7	·184	+24·4	4·2	2·1	4·3
									4·4	3·4	2·2

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
265	3·2	0·0	.....	−1·2	.....	0·6	0·6	0·9	0·5	1·6	.....	0·8			
	2·1	−0·4	−3·2	−1·2	.....	.....	3·2	.....	.....	2·4	2·0	0·8:	.....	·007	
266	.....	−0·6	0·8	−1·0	0·6	.....	.....	.....	.....	.....	.....	−0·4			
	1·2	1·0	−0·4	−3·8	1·0	.....	.....	.....	.....	.....	.....	−0·3	.....	·004	
267	.....	.....	6·0	3·1	3·2	.....	.....	.....	.....	.....	.....	4·3			
	.....	.....	2·8	2·8	3·2	.....	.....	.....	.....	.....	.....	3·8	.....	·023	
268	.....	.....	0·5	3·3	1·1	.....	.....	.....	.....	.....	.....	1·5			
	.....	.....	1·4	0·6	2·1	.....	.....	.....	.....	.....	.....	1·5	.....	·016	
269	.....	.....	.....	−0·5	.....	−0·2	−0·5	−0·9	−1·0	−1·2	−1·2	−0·8			
	.....	−1·8	−0·5	0·6	.....	−0·7	−0·9	−1·2	−1·4	−1·2	−0·8	−0·9	−0·8	·016	·026
270	−0·7	−1·2	−4·4	−6·0	−6·0	−4·7	−7·0	−5·5	−3·8	−4·0	.....	−4·2			
	−3·1	−2·8	−4·4	−4·6	.....	−5·8	−5·5	−5·8	−5·5	−4·0	−6·0	−4·5	−3·6	·001	
271	6·0	.....	−0·5	.....	.....	.....	.....	.....	.....	.....	.....	1·6			
	3·3	−0·1	−0·2	.....	.....	.....	.....	.....	.....	.....	.....	1·6:	.....	·016	
272	−0·3	0·0	0·4	−1·2	2·8	0·8	0·3	−2·5	−0·3	2·0	.....	0·3			
	0·3	0·0	−0·6	−3·1:	−0·8	−0·4	−0·5	0·2	−1·5	2·4	.....	0·1	.....	·010	
273	2·5	3·4	0·8	2·0	0·6	1·0	1·6	2·1	2·4	2·2	.....	2·0			
	2·1	2·3	2·2	3·8	3·4	1·0	1·3	2·2	2·7	1·0	.....	2·3	2·9	·017	·004
274	2·4	2·8	2·0	1·6	−0·4	1·2	0·6	−1·8	−1·4	2·0	.....	1·0			
	1·2	0·2	2·0	−0·9	.....	0·3	0·8	.....	0·0	1·4	.....	0·8	.....	·010	
275	.....	.....	−1·5	−3·3	−2·2	.....	.....	.....	.....	.....	.....	−2·8			
	.....	.....	−0·9	−2·6	−2·5	.....	.....	.....	.....	.....	.....	−2·4	−1·9	·003	·031
276	0·8	0·5	.....	−0·6	.....	−0·7	−0·7	0·0	−0·9	−0·2	.....	−0·3			
	1·5	−0·8	0·9	1·0	0·4	−1·4	−0·6	−0·3	0·2	1·5	0·2	0·3	0·7	·007	·017
277	.....	.....	−0·4	2·8	2·0	.....	.....	.....	.....	.....	.....	1·8			
	4·1	.....	1·7	0·2	2·4	.....	.....	.....	.....	.....	.....	2·2	.....	·012	
278	3·2	2·8	−1·5	−1·6	3·8	.....	.....	.....	.....	.....	.....	1·8			
	3·0	2·6	0·1	−0·6	1·3	1·8	.....	.....	.....	.....	.....	1·6	2·9	·014	·035
279	.....	.....	5·5	5·6	3·3	.....	.....	.....	.....	.....	.....	4·6			
	.....	.....	3·4	3·0	4·3	.....	.....	.....	.....	.....	.....	3·8	.....	·032	
280	−0·5	−0·3	0·9	−0·8	0·0	0·1	−0·9	0·5	0·2	2·0	.....	0·0			
	0·3	1·0	0·6	−1·5	1·8	0·8	1·9	.....	.....	0·8	0·1	0·8	.....	·012	
281	−1·0	−0·2	−3·0	−1·7	−2·7	−1·0	−2·0	−3·6	−3·6	−1·5	.....	−2·1			
	−1·7	−1·2	−1·8	−2·3	0·1	−1·8	−0·6	−1·2	−3·4	−2·2	.....	−1·7	−1·4	·010	·009
282	1·3	1·1	2·4	3·0	0·7	2·0	.....	.....	.....	.....	.....	2·0			
	1·2	1·3	2·2	0·3	0·3	1·9	0·9	.....	.....	1·0	.....	1·4	.....	·017	
283	0·3	0·0	.....	−1·6	.....	−1·6	−0·1	−0·5	0·6	−0·4	.....	−0·4			
	−1·6	−0·5	−2·2	−1·6	.....	.....	0·4	−0·2	−0·5	0·3	−0·7	−0·7	.....	·006	
284	4·0	.....	4·3	4·8	4·4	.....	.....	.....	.....	.....	.....	4·1			
	5·2	.....	5·1	3·9	4·9	.....	.....	.....	.....	.....	.....	4·7	4·3	·066	·064
285	.....	.....	−1·2	4·1	2·2	.....	.....	.....	.....	.....	.....	0·8:			
	.....	.....	−1·2	3·2	2·2	.....	.....	.....	.....	.....	.....	0·8:	2·0	·030	·050
286	−0·6	0·0	0·8	0·7	0·0	0·7	0·8	1·6	1·3	1·7	.....	0·7			
	0·2	0·3	1·3	−0·4	2·4	1·9	2·7	1·3	0·6	1·8	0·8	1·2	.....	·013	
287	.....	.....	3·3	.....	.....	.....	.....	.....	.....	.....	.....	1·6:			
	.....	.....	3·7	0·6	3·7	.....	.....	.....	.....	.....	.....	2·4	.....	·016	
288	2·4	.....	4·0	5·0	3·4	.....	.....	.....	.....	.....	.....	3·6			
	4·3	.....	3·6	2·8	2·2	.....	.....	.....	.....	.....	.....	3·3	.....	·027	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
289	Boss 1776	Bu. 3678	06 48·6	58 33	4·9	G5	·134	+ 9·9	2·5 3·2	1·9 2·3	....
290	Boss 1794	.....	06 52·3	38 12	6·2	K2	·132	+16·2	−1·5 −0·8	−0·3 −0·2	....
291	Boss 1803	41 Gemin.	06 54·5	16 13	5·9	K2	·016	+ 8·0	....	....	....
292	Boss 1809	.....	06 57·2	29 31	6·0	G2	·838	+10·7	4·1 4·7	5·3 5·9	5·3 5·1
293	Boss 1813	.....	06 58·1	11 06	5·2	K2	·033	+ 6·7	2·7 0·2	....	....
294	Boss 1815	ζ Gemin.	06 58·2	20 43	4·0	G0	·008	− 5·3	−3·5 −4·0	−3·0 −2·8	−4·2 −3·4
295	Boss 1822	.....	06 59·6	34 38	5·6	G4	·086	− 4·7	1·8 1·5	2·0 0·9	0·8 1·6
296	Boss 1824	17 Lyncis	07 00·6	60 57	6·7	K2	·050	+ 2·5	....	..... 0·9	....
297	H.R. 2665	.....	07 00·9	34 09	6·1	K5	.....	.....	....	....	....
298	Boss 1835	.....	07 02·6	16 05	5·6	K0	·110	−31·2	1·6 0·4	0·0 1·9	....
299	Boss 1840	τ Gemin.	07 04·8	30 25	4·5	K3	·051	+13·2	1·2 2·0	1·2 1·0	....
300	Boss 1846	.....	07 05·6	51 36	5·7	M4	·019	−51·7	−2·6 −1·5	....	....
301	Boss 1850	.....	07 06·3	24 17	5·8	F5	·054	+ 2·3	−0·8 0·8	1·8 1·5	−4·0 −1·4
302	Boss 1854	18 Lyncis	07 07·2	59 49	5·3	K0	·271	+23·3	3·7 4·3	1·7 1·6	....
303	Boss 1860	.....	07 08·4	47 25	5·6	F9	·184	+84·2	6·1 6·0	5·5 5·2	4·8 6·0
304	Boss 1864	.....	07 09·0	12 17	5·8	K0	·058	+14·8	0·0 −0·4	−0·1 1·6	....
305	Boss 1868	53 Gemin.	07 09·7	28 05	5·9	M0	·019	+12·4	....	....	....
306	Boss 1871	.....	07 10·1	82 36	5·1	M5	·044	+19·0	....	....	....
307	Boss 1914	56 Gemin.	07 16·1	20 38	5·2	K8	·066	− 8·3	....	....	....
308	Boss 1919	66 Aurigae	07 17·2	40 52	5·3	K0	·023	+16·6	....	....	....
309	Boss 1940	.....	07 21·0	21 45	6·4	F5	·308	+37·0	4·1 4·5	5·2 4·1	..... 4·6
310	Boss 1945	63 Gemin.	07 21·8	21 39	6·0†	F4	·131	+ 0·3	4·3 2·2	1·9 2·3	1·3 2·6
311	Boss 1948	.....	07 22·3	49 53	5·4	F7	·145	−30·6	4·8 4·2	5·2 4·4	4·6 4·4
312	Boss 1950	.....	07 22·6	07 09	5·3	F0	·044	+ 3·4	1·0 1·3	1·8 3·3	1·3 0·8

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
289	0·6	3·0	3·5	3·8	2·5	3·1	2·8	1·1	1·6	1·5	.....	**2·3**			
	1·8	1·4	4·4	3·8	3·4	1·5	1·5	1·5	.....	.....	.....	**2·5**	0·1	**·032**	·029
290	1·5	0·0	0·0	−1·7	−1·4	−1·0	0·8	0·7	−0·6	−2·0	.....	**−0·5**			
	.....	.....	−1·7	−2·0	−0·9	.....	1·0	.....	−1·2	−1·7	−1·1	**−0·9**	.....	**·004**	
291	.....	−2·6	.....	−3·3	.....	.....	−3·0	−3·3	−3·0	−2·9	.....	**−3·0**			
	−3·0	−1·2	.....	−3·8	.....	.....	−0·4	−1·0	−2·8	−1·8	−1·7	**−2·0**	.....	**·002**	
292	3·9	.....	4·8	5·6	3·9	.....	.....	.....	.....	.....	.....	**4·6**			
	3·5	.....	5·7	5·5	5·5	.....	.....	.....	.....	.....	.....	**5·1**	5·1	**·059**	·061
293	0·5	0·3	0·8	−2·0	.....	0·0	−1·5	−0·8	−0·6	−0·4	.....	**−0·1**			
	1·3	1·1	−0·4	−1·6	.....	0·3	0·3	1·0	0·0	−0·4	−0·5	**0·1**	.....	**·009**	
294	.....	.....	−3·7	−0·9	−3·8	.....	.....	.....	.....	.....	.....	**−3·2**			
	−2·6	.....	−2·9	−3·6	−3·3	.....	.....	.....	.....	.....	.....	**−3·2**	−3·4	**·004**	·015
295	0·4	0·8	0·4	−0·9	0·6	.....	.....	.....	.....	.....	.....	**0·8**			
	1·0	1·4	0·4	−0·6	3·2	.....	.....	.....	.....	.....	.....	**1·2**	0·1	**·012**	·036
296	−0·5	0·0	.....	−1·6	.....	0·2	−0·4	0·9	0·8	1·3	.....	**0·1**			
	0·9	−0·4	−1·4	−1·8	.....	.....	−1·2	.....	0·6	1·4	−0·4	**−0·2**	.....	**·005**	
297	0·8	−0·5	.....	−2·7	.....	−1·6	−1·7	−0·4	−1·3	−1·2	.....	**−1·1**			
	1·0	−0·6	.....	−1·2	.....	.....	−3·0	−1·2	−2·4	−0·5	−0·8	**−1·1**	.....	**·004**	
298	1·0	1·0	0·2	−1·5	2·0	0·9	0·5	0·8	0·1	0·8	.....	**0·6**			
	0·2	0·7	0·8	−0·8	0·4	1·4	0·0	.....	.....	1·4	.....	**0·6**	.....	**·010**	
299	−0·3	0·0	1·3	0·2	0·4	1·0	2·7	2·0	0·2	3·0	.....	**1·1**			
	−0·2	−0·6	1·0	0·9	0·9	0·1	1·6	0·1	2·3	2·4	2·5	**1·1**	0·5	**·021**	·010
300	.....	.....	.....	−2·2	.....	−2·0	−2·4	−1·2	−0·9	−1·6	−1·6	**−1·8**			
	.....	−1·2	−0·9	−1·4	.....	−1·5	−2·2	−0·1	−1·2	−1·6	−1·5	**−1·3**	0·1	**·004**	·002
301	.....	.....	−2·0	.....	0·7	.....	.....	.....	.....	.....	.....	**−0·9**			
	.....	.....	−2·2	1·2	1·4	.....	.....	.....	.....	.....	.....	**0·2**:	.....	**·006**	
302	2·7	0·5	5·6	.....	2·8	1·9	.....	2·8	2·4	0·4	.....	**2·4**			
	1·7	0·8	5·4	5·0	2·4	2·6	1·9	2·7	2·3	1·3	0·5	**2·5**	1·3	**·027**	·036
303	4·1	.....	5·5	4·7	5·1	.....	.....	.....	.....	.....	.....	**5·1**			
	3·2	.....	3·6	4·4	6·6	.....	.....	.....	.....	.....	.....	**5·0**	5·0	**·077**	·069
304	−0·8	−1·0	−0·3	−1·2	0·0	0·6	1·7	0·1	0·0	1·0	.....	**0·0**			
	1·5	1·2	−2·7	−2·4	2·0	0·8	1·4	.....	.....	−0·1	.....	**0·3**	.....	**·007**	
305	.....	.....	.....	.....	.....	.....	−0·8	−1·0	0·0	−1·1	1·2	**−0·4**:			
	.....	−2·8	.....	−2·8	.....	.....	0·0	−0·2	−1·3	−0·6	0·1	**−1·1**:	−0·2	**·005**	·008
306	.....	.....	.....	−2·5	.....	−1·0	0·7	0·3	−0·6	−1·2	−2·0	**−0·9**			
	....	−2·4	−2·9	−2·0	.....	−1·2	−1·9	0·2	−1·6	−0·9	−1·9	**−1·6**	.....	**·005**	
307	0·8	−0·5	.....	−1·1	.....	−1·6	0·2	0·2	−0·1	0·0	.....	**−0·3**			
	0·9:	0·1:	−0·6	−0·8	0·2	1·1	−0·3	0·0	−0·3	0·4	0·1	**0·1**	.....	**·009**	
308	.....	.....	.....	.....	.....	.....	−1·9	−1·4	−0·3	−0·9	.....	**−1·1**:			
	.....	−1·3	.....	0·8	.....	.....	−1·2	−0·7	−0·3	−1·2	−2·0	**−0·8**:	−0·3	**·006**	−·061
309	.....	.....	6·0	4·1	3·0	.....	.....	.....	.....	.....	.....	**4·5**			
	.....	.....	3·8	3·2	3·7	.....	.....	.....	.....	.....	.....	**4·0**	3·9	**·037**	·040
310	.....	.....	5·4	3·4	4·2	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	4·1	2·6	2·6	.....	.....	.....	.....	.....	.....	**2·7**	2·8	**·026**	·058
311	.....	.....	4·4	.....	4·3	.....	.....	.....	.....	.....	.....	**4·7**			
	4·6	.....	3·2	3·6	4·1	.....	.....	.....	.....	.....	.....	**4·1**	.....	**·063**	
312	.....	.....	0·8	.....	0·9	.....	.....	.....	.....	.....	.....	**1·2**			
	.....	.....	2·1	0·7	0·8	.....	.....	.....	.....	.....	.....	**1·5**	.....	**·016**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
313	Boss 1952	ρ Gemin.	07 22·7	31 59	4·2	A8	·237	−13·8	2·6 2·6	3·0 3·3	3·0 1·0
314	Boss 1953	γ Canis Min.	07 22·8	09 08	4·6	K5	·062	+32·6	....	....	....
315	Boss 1962	6 Canis Min.	07 24·2	12 13	4·8	K4	·019	−28·2	..... 0·8	....	....
316	Boss 1974	.....	07 26·9	02 08	5·3	A8	·012	+16·6	1·4 2·6	1·6 2·3	2·5 1·8
317	Boss 1980	.....	07 28·7	56 00	6·0	K3	·044	+ 1·9	1·3 0·2	2·0 2·4	....
318	Boss 1981	.....	07 28·8	31 11	5·8†	K0	·031	−13·7	2·4 1·3	1·2 1·7	....
319	Boss 1987	υ Gemin.	07 29·8	27 07	4·2	K7	·119	−29·6	−0·3 0·6	....	....
320	Boss 2001	ο Gemin.	07 32·6	34 49	4·9	F1	·123	− 0·8	1·2 0·1	0·3 0·1	0·5 0·0
321	Boss 2008	α Canis Min.	07 34·1	05 29	0·5	F5	1·241	−19·2	2·7 2·8	2·6 3·1	3·2 2·6
322	Boss 2020	.....	07 36·4	14 26	5·8	M4	·014	−28·3	....	....	....
323	Boss 2023	σ Gemin.	07 37·0	29 07	4·3	K0	·247	+36·9	1·1 −0·2	1·5 2·5	....
324	Boss 2028	76 Gemin.	07 38·1	26 01	5·4	K6	·032	− 6·8	..... −0·1	....	....
325	Boss 2029	κ Gemin.	07 38·4	24 38	3·7	G7	·064	+11·3	1·2 0·8	0·6 0·3	....
326	Boss 2031	β Gemin.	07 39·2	28 16	1·2	G9	·624	− 5·4	2·5 3·7	1·0 1·4	....
327	Boss 2034	.....	07 39·8	80 31	6·5	G9	·480	− 0·5	3·4 4·1	5·4 5·3	....
328	Boss 2040	81 Gemin.	07 40·3	18 45	5·0	K8	·094	+66·4	0·3 1·4	....	....
329	Boss 2049	π Gemin.	07 41·1	33 40	5·3	M0	·039	−20·5	....	....	....
330	Boss 2092	.....	07 50·0	09 07	5·8	F3	·086	+ 6·3	4·3 4·0	4·5 4·2	2·3 1·6
331	H.R. 3093	.....	07 51·2	04 44	6·3	G9	.....	.....	....	0·9	....
332	Boss 2101	.....	07 53·0	59 20	5·8	F2	·033	−39·4	−0·2 −1·4	−1·3 −0·5	3·9 2·0
333	Boss 2112	54 Camelop.	07 54·5	57 33	7·4†	F9	·074	+22·3	1·7 2·0	2·0 2·6	1·9 2·2
334	Boss 2130	.....	07 57·1	02 36	4·5	K2	·106	+56·8	..... 3·1	2·2 2·4	....
335	Boss 2155	29 Monocer.	08 03·6	−02 41	4·4	G1	·022	+13·7	−3·3 −2·1	−1·8 −1·2	−1·3 −2·6
336	Boss 2156	13 Cancri	08 04·1	26 08	6·7	K4	·038	−3·6	....	....	....

Continued

No.	4455 / 62	4455 / 91	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 91	Victoria M	Mt.W. M	Victoria π	Trig. π
313	.....	.....	2·7	2·0	3·3	.....	.....	.....	.....	.....	.....	2·8			
	.....	.....	1·4	.....	2·3	.....	.....	.....	.....	.....	.....	2·1	1·5	·044	·055
314	1·3	−1·4	.....	0·0	.....	−2·1	0·2	1·4	−0·9	−1·3	.....	−0·4			
	1·2	.....	−2·4	0·4	.....	−0·2	−1·3	0·0	−2·2	−1·0	−1·2	−0·7	.....	·009	
315	−0·2	0·0	.....	−0·6	.....	−1·0	−0·6	0·0	−0·3	0·5	.....	−0·3			
	0·6	0·6	−1·3	0·2	2·0	1·2	−0·3	−0·9	−3·0	−1·2	−0·7	−0·2	0·4	·010	
316	2·7	.....	2·5	.....	.....	.....	.....	.....	.....	.....	.....	2·1			
	2·1	−0·4	1·2	.....	.....	.....	.....	.....	.....	.....	.....	1·6	.....	·020	
317	3·7	1·7	3·1	0·0	0·2	2·0	−0·3	2·9	2·3	2·8	.....	1·8			
	2·0	1·1	1·0	−0·5	0·7	1·8	1·3	.....	.....	2·8	0·4	1·2	.....	·012	
318	2·0	1·2	1·7	−0·2	1·5	1·6	1·9	.....	.....	.....	.....	1·5			
	0·9	1·7	−0·6	−0·2	0·5	1·4	4·0	.....	.....	2·4	.....	1·3	.....	·016	
319	0·5	0·3	.....	1·7	.....	0·5	−0·1	2·5	0·9	−0·9	.....	0·6			
	−1·0	0·4	0·6	2·5	−0·2	0·6	0·2	0·3	0·2	0·0	0·0	0·4	0·5	·018	·015
320	.....	.....	−0·6	.....	1·5	.....	.....	.....	.....	.....	.....	0·6			
	.....	.....	1·6	.....	2·3	.....	.....	.....	.....	.....	.....	0·8	0·8	·014	·023
321	.....	.....	2·2	3·5	3·0	.....	.....	.....	.....	.....	.....	3·0			
	.....	.....	2·5	4·1	3·1	.....	.....	.....	.....	.....	.....	3·0	3·2	·316	·309
322	.....	.....	.....	−2·9	.....	−1·6	−0·2	−1·2	−1·8	−1·0	−0·4	−1·3			
	.....	−2·0	.....	−2·6	.....	−2·7	0·2	−0·6	−2·2	−1·2	−0·4	−1·3	.....	·004	·006
323	2·4	1·3	4·9	2·5	−0·7	2·7	3·3	3·5	0·8	2·3	.....	2·1			
	2·1	2·2	4·2	1·0	0·4	.....	1·6	2·0	2·0	3·1	0·1	1·8	2·6	·034	·027
324	1·3	0·5	.....	−1·0	.....	−1·8	−0·4	−0·1	−0·3	−1·1	.....	−0·4			
	.....	−0·3	−0·9	−0·8	.....	1·2:	0·4	1·3	−0·2	−0·4	−0·2	0·0	.....	·008	
325	.....	.....	−0·1	1·3	0·6	1·1	3·5	2·3	−0·3	2·2	.....	1·2			
	.....	.....	1·9	2·9	.....	0·3	1·6	1·6	0·6	2·0	.....	1·3	0·9	·032	·024
326	3·8	2·1	3·2	4·2	0·0	3·3	2·8	2·9	2·4	1·5	.....	2·4			
	1·6	1·7	3·2	3·8	2·1	2·6	2·2	1·9	.....	2·2	.....	2·4	1·7	·174	·064
327	6·2	4·7	3·8	4·2	3·8	.....	.....	.....	.....	.....	.....	4·5			
	3·7	4·9	4·1	6·8	4·5	5·4	5·1	.....	.....	.....	.....	4·9	4·8	·044	·049
328	0·5	0·3	.....	−0·1	.....	−0·1	0·0	0·3	−0·1	−0·1	.....	0·1			
	1·1	1·2	−0·2	−0·4	−0·4	1·9	1·5	−0·4	−1·9	0·0	0·6	0·4	.....	·011	
329	.....	.....	.....	−1·1	.....	−2·7	−1·7	−1·2	−2·1	−0·8	−2·4	−1·7			
	.....	−0·3	.....	−0·2	.....	−1·9	−2·0	−0·6	−1·2	−0·9	−0·9	−1·0	0·3	·005	·028
330	.....	.....	5·2	.....	3·3	.....	.....	.....	.....	.....	.....	3·9			
	.....	.....	3·0	3·4	2·6	.....	.....	.....	.....	.....	.....	3·1	.....	·034	
331	3·3	2·3	0·0	−0·5	.....	.....	0·6	0·9	−0·3	0·1	.....	0·8			
	1·6	2·0	−0·9	−2·0	.....	.....	1·0	0·5	−0·4	0·8	.....	0·3:	.....	·007	
332	.....	.....	1·3	−0·2	1·7	.....	.....	.....	.....	.....	.....	0·8			
	.....	.....	−0·4	0·6	1·1	.....	.....	.....	.....	.....	.....	0·2	.....	·009	
333	2·1	.....	1·8	.....	−0·5	.....	.....	.....	.....	.....	.....	1·5			
	3·9	.....	0·7	−1·2	0·6	.....	.....	.....	.....	.....	.....	1·5	.....	·007	
334	1·1	0·5	0·4	−1·2	0·0	−1·5	0·3	1·3	−0·9	−1·0	.....	0·1			
	0·6	2·2	0·4	−0·6	−0·4	0·3	1·0	0·5	0·9	−1·1	−1·5	0·6	1·1	·015	·030
335	.....	.....	−2·6	−2·3	−1·2	.....	.....	.....	.....	.....	.....	−2·1			
	−1·5	.....	−3·6	−3·2	.....	−2·5	−2·5	−3·4	.....	.....	.....	−2·5	−4·2:	·005	
336	0·3	−1·4	.....	−0·7	.....	−1·0	−0·1	−0·3	−1·1	−1·0	.....	−0·7:			
	.....	.....	−2·5	−1·6	.....	−0·6	1·5	.....	−2·4	−1·0	−0·7	−1·0:	.....	·003	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
337	Boss 2157	14 Cancri	08 04·4	25 50	5·8	G5	·360	−53·7	3·3 4·5	3·8 2·8	....
338	Boss 2168	ζ Cancri A	08 06·5	17 56	5·6	F8	·155	−16·0	3·4 3·8	4·2 4·2	4·1 3·9
339	Boss 2169	ζ Cancri C	08 06·5	17 57	6·0	G0	·143	−25·7	3·0 2·8	4·5 5·1	4·6 4·8
340	Boss 2182	.....	08 08·8	59 30	6·7	K4	·038	−27·8	....	....	....
341	Boss 2195	β Cancri	08 11·1	09 30	3·8	K4	·072	+10·5	0·8 0·8	....	....
342	Boss 2197	.....	08 12·4	58 03	5·9	F3	·060	−16·0	2·5 3·6	2·3 4·8	2·7 3·6
343	Boss 2202	χ Cancri	08 14·0	27 32	5·2	F7	·387	+22·4	5·0 4·2	4·3 4·8	4·4 4·7
344	Boss 2205	.....	08 14·5	21 04	5·9	K2	·091	−29·1	0·0	3·3	....
345	Boss 2208	31 Lyncis	08 16·0	43 31	4·4	K6	·106	+21·3	0·5 −0·7	....	....
346	Boss 2229	25 Cancri	08 20·1	17 23	6·2	F3	·243	+26·2	2·3 2·2	1·6 1·6	3·4 1·9
347	Boss 2232	22 Cancri	08 20·4	28 14	5·8	K7	·133	+16·6	0·8 1·6:	....	....
348	Boss 2234	.....	08 20·5	07 53	5·2	G5	·041	+ 1·0	0·9 0·3	0·2 0·8	....
349	Boss 2238	.....	08 20·7	24 52	7·1	A3	·094	+ 7·0	1·1 2·8	4·1 5·0	2·4 −0·2
350	Boss 2251	28 Cancri	08 22·7	24 28	6·1	A6n	·075	+ 2·4	1·5 1·6	3·9 2·6	1·6 0·8
351	Boss 2271	η Cancri	08 26·9	20 47	5·5	K2	·064	+12·6	....	2·4 1·2	....
352	Boss 2272	32 Lyncis	08 26·9	36 46	6·1	F3	·138	− 3·4	4·8 4·6	2·0 3·4	3·9 4·2
353	Boss 2284	.....	08 30·3	65 22	5·7	G1	·087	− 8·8	3·9 5·4	5·3 5·0	5·0 4·3
354	Boss 2285	Bu. 4677 (br.)	08 30·5	06 58	6·0	F8	·192	+15·5	3·6 3·2	3·9 3·8	3·6 2·9
355	Boss 2290	π Ursae Maj.	08 31·5	64 40	4·8	K0	·053	+17·4	1·2 3·0	0·9 1·7	....
356	Boss 2302	σ Hydrae	08 33·5	03 42	4·5	K3	·024	+14·1	−0·3 2·1	1·4	....
357	Boss 2306	34 Lyncis	08 34·1	46 11	5·5	K0	·084	−39·8	1·6 2·6	1·8 2·4	....
358	Boss 2308	39 Cancri	08 34·4	20 22	6·5	G9	·042	+26·1	1·2	1·0 2·2	....
359	Boss 2310	.....	08 34·6	20 01	6·4	G7	·039	+25·4	1·7 0·6	1·5 1·4	....
360	Boss 2311	.....	08 34·6	19 54	6·3	A2	·033	+29·3	1·2 1·2	2·1 1·5	3·0 2·0

Continued

No.	4455 / 62	4455 / 91	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4155 / 82	4155 / 89	4489 / 91	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
337	4·5	3·2	3·0	3·5	2·9	2·0	.....	.....	.....	.....	.....	3·3			
	3·2	2·8	3·0	2·8	3·4	.....	2·9	3·0	.....	.....	.....	3·2	3·2	·031	·036
338	5·2	.....	3·9	4·8	3·8	.....	.....	.....	.....	.....	.....	4·2			
	3·2	.....	4·5	4·3	3·8	.....	.....	.....	.....	.....	.....	4·0	3·5	·050	·038
339	4·9	.....	6·0	6·3	4·4	.....	.....	.....	.....	.....	.....	4·8			
	3·6	.....	5·9	5·3	4·2	.....	.....	.....	.....	.....	.....	4·5	4·4	·054	·038
340	1·8	0·4	.....	0·4	.....	−1·3	−1·0	−0·5	−0·6	−0·5	.....	−0·2			
	1·9	0·9	0·1	−0·4	.....	−0·6	−1·4	0·0	0·0	0·0	0·1	−0·0	.....	·004	
341	0·6	−0·5	.....	0·0	.....	−0·7	−0·1	6·0	−1·8	−1·8	.....	−0·4			
	−0·5	−1·3	.....	0·1	−0·5	−1·4	1·2	0·0	−0·7	−1·6	0·2	−0·3	0·4	·015	·003
342	.....	.....	2·2	.....	3·4	.....	.....	.....	.....	.....	.....	2·6			
	.....	.....	0·9	2·7	2·2	.....	.....	.....	.....	.....	.....	3·0	.....	·024	
343	5·1	.....	4·7	4·9	4·4	.....	.....	.....	.....	.....	.....	4·7			
	.....	.....	4·4	4·2	4·6	.....	.....	.....	.....	.....	.....	4·4	3·6	·074	·066
344	1·2	2·2	1·4	0·5	1·7	0·2	1·9	1·5	0·2	1·5	.....	1·3			
	0·9	0·5	0·0	0·7	0·4	1·5	1·3	.....	.....	1·4	1·2	0·9	.....	·011	
345	0·8	0·3	.....	1·7	.....	−1·8	0·4	1·3	−0·1	−0·9	.....	0·2			
	.....	−0·5	−0·4	0·7	−0·6	0·2	0·2	0·6	0·2	0·8	0·4	0·1	0·7	·014	·009
346	.....	.....	3·6	.....	2·0	.....	.....	.....	.....	.....	.....	2·5			
	.....	.....	2·6	2·4	1·2	.....	.....	.....	.....	.....	.....	2·0	2·8	·016	
347	2·6	0·3	.....	−0·8	.....	−0·7	2·8	0·7	−0·3	−0·2	.....	0·6			
	1·1	0·8	−0·6	−0·4	1·9	0·6	1·0	0·0	−0·8	0·6	0·6	0·5	.....	·009	
348	1·0	0·8	1·0	0·8	0·2	1·0	.....	.....	.....	.....	.....	0·7			
	0·6	0·4	1·6	−0·4	.....	0·6	.....	.....	.....	.....	.....	0·6	−0·4	·012	
349	.....	.....	3·0	.....	2·1	.....	.....	.....	.....	.....	.....	2·5			
	.....	.....	1·1	3·3	3·5	.....	.....	.....	.....	.....	.....	2·6	.....	·012	
350	.....	.....	2·7	.....	1·9	.....	.....	.....	.....	.....	.....	2·3			
	.....	.....	2·0	1·3	.....	.....	.....	.....	.....	.....	.....	1·7	.....	·015	
351	0·0	0·6	1·4	−0·4	.....	0·4	−2·1	0·3	2·2	0·9	.....	0·6			
	0·6	−0·4	−1·7	−0·9	.....	0·7	−2·3	.....	2·3	2·0	0·8	0·2	.....	·010	
352	.....	.....	4·6	3·7	3·2	.....	.....	.....	.....	.....	.....	3·7			
	.....	.....	3·0	3·4	4·0	.....	.....	.....	.....	.....	.....	3·8	3·1:	·034	·043
353	6·3	.....	5·3	6·3	3·8	.....	.....	.....	.....	.....	.....	5·1			
	5·3	.....	5·3	4·2	4·0	.....	.....	.....	.....	.....	.....	4·8	.....	·070	·060
354	3·4	.....	3·7	4·5	5·0	.....	.....	.....	.....	.....	.....	4·0			
	3·6	.....	4·8	3·4	4·8	.....	.....	.....	.....	.....	.....	3·8	4·0	·038	·024
355	2·2	1·8	3·4	2·7	1·7	1·4	1·1	2·8	1·6	−0·2	.....	1·7			
	1·4	0·8	2·3	2·5	0·8	1·4	−0·1	1·7	0·9	0·6	.....	1·4	1·0	·022	·018
356	−0·2	1·8	.....	0·8	.....	3·4	0·6	1·0	−1·4	1·6	.....	0·9			
	0·7	1·9	0·1	0·1	2·0	3·5	0·4	.....	−2·0	1·7	−1·1	0·9	−0·1	·019	
357	3·7	2·7	3·5	1·6	0·0	2·6	.....	.....	.....	.....	.....	2·2			
	1·6	1·8	1·1	1·5	1·0	3·5	2·4	.....	.....	2·1	.....	2·0	.....	·021	
358	1·5	0·0	−0·1	−0·5	0·0	−0·2	−1·2	−1·0	−0·3	2·7	.....	0·3			
	0·4	−0·8	0·8	−0·6	.....	0·1	1·5	.....	1·0	2·2	.....	0·8	.....	·006	
359	0·5	0·5	1·2	1·3	1·3	1·1	0·0	0·9	1·2	2·5	.....	1·1			
	0·9	−0·2	1·6	−1·4	.....	1·0	0·9	.....	1·5	2·3	.....	0·9	.....	·008	
360	.....	.....	0·8	.....	0·1	.....	.....	.....	.....	.....	.....	1·4			
	.....	.....	2·7	0·7	0·4	.....	.....	.....	.....		.....	1·4	.....	·010	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
361	Boss 2313	.....	08 35·2	20 04	6·7	A4	.....	.....	1·1 1·8	3·1 3·1	1·2 2·2
362	Boss 2336	δ Cancri	08 39·0	18 31	4·2	K1	·241	+ 8·2	0·3 2·2	0·7 1·8	....
363	Boss 2338	46 Cancri	08 39·2	31 04	6·1	G6	·018	−18·4	....	2·6 2·5	....
364	Boss 2348	ι Cancri	08 40·6	29 08	4·2	G5	·051	+ 9·5	−0·6 −0·5	−0·2 −1·8	....
365	Boss 2364	.....	08 44·3	33 41	6·2	F9	·111	− 4·1	3·1 4·6	4·7 5·1	3·8 3·0
366	Boss 2377	.....	08 46·4	32 51	5·8	A2	·012	−23·6	1·3 2·0	1·5 2·8	4·8 3·2
367	Boss 2380	55 Cancri	08 46·6	28 43	6·1	K2	·536	+21·3	7·0 5·2	5·2 4·5	....
368	Boss 2383	6 Ursae Maj.	08 48·1	64 59	5·6	G5	·087	+ 1·6	1·5 3·5	0·9 1·8	..... 3·0:
369	.....	W.B. 8h 1147	08 49·0	26 36	6·7	G5	·440	+26·4	..... 4·0	5·1 4·4	3·6 .....
370	Boss 2392	.....	08 50·1	46 01	5·9	K2	·117	+57·8	0·3 1·0	1·8 2·4	....
371	Boss 2393	ζ Hydrae	08 50·1	06 20	3·3	G7	·100	+11·4	−0·7 −1·1	1·2 0·0	....
372	Boss 2402	.....	08 52·0	15 58	5·6	A4	·068	−20·4	1·8 1·3	3·5 4·6	2·7 1·0
373	Boss 2411	ρ Ursae Maj.	08 53·5	68 01	5·0	M2	·023	+10·9	−0·8 −0·6	....	....
374	Boss 2413	10 Ursae Maj.	08 54·2	42 11	4·1	F5	·502	+22·9	3·3 3·4	2·1 3·6	3·6 3·5
375	Boss 2430	.....	08 58·3	51 14	6·7	F3	·130	+17·3	3·3 3·3	3·6 4·1	4·1 3·6
376	Boss 2432	.....	08 58·5	48 55	5·6	F4*n*	·026	+ 1·4	0·4 −1·0	−0·7 1·3	0·0 −1·6
377	Boss 2437	.....	09 00·2	38 51	4·7	G3	·040	+14·4	−1·1 −2·0	−3·4 −1·8	−0·7 −1·2
378	Boss 2439	.....	09 00·7	05 30	5·4	K3	·018	+14·9	−1·4 −0·6	..... 0·6	....
379	Boss 2447	75 Cancri	09 03·0	27 03	6·0	G2	·402	+ 6·1	6·0 5·1	4·1 4·4	5·9 4·8
380	Boss 2463	.....	09 06·4	61 50	5·2	F8	·030	−11·7	4·5 4·7	3·0 3·2	4·1 4·6
381	Boss 2474	.....	09 08·5	57 10	5·5	M0	·034	−28·8	−0·8 0·1	....	....
382	Boss 2507	α Lyncis	09 15·0	34 49	3·3	K8	·215	+34·8	−0·8 0·1	....	....
383	H.R. 3707	.....	09 15·4	33 21	6·2	K3:	.....	.....	....	....	....
384	Boss 2524	κ Leonis	09 18·8	26 37	4·6	K2	·059	+22·9	1·2 2·0	1·1	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
361	.....	.....	2·7	.....	1·9	.....	.....	.....	.....	.....	.....	**2·0**			
	.....	.....	2·5	.....	.....	.....	.....	.....	.....	.....	.....	**2·4**	.....	**·012**	
362	1·2	0·1	0·6	1·5	1·7	1·4	0·3	0·7	0·4	1·8	.....	**0·9**			
	−0·4	1·0	2·3	1·5	1·4	2·2	0·7	0·3	0·2	0·6	.....	**1·2**	0·8	**·023**	·018
363	.....	.....	0·1	−1·0	0·4	1·1	−2·3	−0·6	0·2	0·8	.....	**0·1**			
	1·0	0·5	1·6	−1·8	−0·4	−1·0	−0·2	1·0	0·9	0·7	.....	**0·4**:	−1·0	**·007**	·007
364	0·1	1·6	0·1	−1·2	1·0	0·7	0·8	0·1	−0·3	1·3	.....	**0·3**			
	−0·8	0·2	−0·3	1·0	1·9	−1·2	−0·1	−0·6	0·9	0·4	.....	**−0·1**	−1·3	**·015**	·028
365	5·5	.....	4·9	3·3	3·7	.....	.....	.....	.....	.....	.....	**4·2**			
	5·5	.....	4·3	2·7	2·6	.....	.....	.....	.....	.....	.....	**4·0**	.....	**·038**	
366	.....	.....	5·6	.....	1·3	.....	.....	.....	.....	.....	.....	**2·9**			
	.....	.....	3·2	2·2	.....	.....	.....	.....	.....	.....	.....	**2·7**	.....	**·025**	
367	5·7	4·2	5·5	7·5	6·3	.....	5·7	5·7	.....	.....	.....	**5·9**			
	5·0	5·2	5·0	4·9	5·5	6·0	5·2	4·7	6·4	5·2	5·4	**5·3**	5·7	**·080**	·080
368	3·8	.....	1·3	3·9	1·4	.....	.....	.....	.....	.....	.....	**2·2**			
	3·4	2·3	1·8	1·3	3·4:	1·8	.....	.....	.....	.....	.....	**2·3**	.....	**·021**	
369	5·5	.....	3·6	5·8	5·3	.....	.....	.....	.....	.....	.....	**4·8**			
	5·4	4·8	3·2	2·3	5·7	.....	.....	.....	.....	.....	.....	**4·3**	4·2	**·037**	·018
370	1·7	2·0	1·3	−0·7	.....	2·3	1·7	2·1	0·4	1·6	.....	**1·3**			
	0·4	0·8	0·8	−1·2	1·5	1·9	1·4	.....	1·4	1·6	.....	**1·1**	.....	**·012**	
371	−0·4	0·6	1·7	1·3	−0·6	−1·1	0·0	0·4	0·2	0·7	.....	**0·3**			
	0·1	1·6	1·6	0·8	2·2	−1·2	0·3	1·2	0·2	0·2	.....	**0·5**	−0·9	**·026**	·017
372	.....	.....	2·3	.....	3·5	.....	.....	.....	.....	.....	.....	**2·7**			
	.....	.....	1·9	.....	.....	.....	.....	.....	.....	.....	.....	**2·2**	.....	**·023**	
373	.....	.....	.....	−1·1	.....	0·8	0·7	0·6	−1·5	−0·4	−0·5	**−0·3**			
	.....	−1·1	−1·0	0·3	.....	−0·1	0·0	0·4	−2·1	−1·6	−1·3	**−0·7**	−0·1	**·008**	
374	.....	.....	3·0	3·7	3·5	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	3·6	3·0	4·4	.....	.....	.....	.....	.....	.....	**3·6**	3·2	**·072**	·066
375	.....	.....	4·6	5·0	3·9	.....	.....	.....	.....	.....	.....	**4·1**			
	.....	.....	4·1	4·7	3·3	.....	.....	.....	.....	.....	.....	**3·8**	.....	**·028**	
376	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**−0·1**:			
	.....	.....	−0·6	−1·7	.....	.....	.....	.....	.....	.....	.....	**−0·7**:	.....	**·006**	
377	.....	.....	−0·6	−1·8	0·7	.....	.....	.....	.....	.....	.....	**−1·2**			
	−1·4	−0·4	0·7	−1·3	1·2	−2·5	−2·0	−3·6	.....	.....	.....	**−1·3**	−2·7	**·006**	·007
378	−0·3	0·5	1·0	−1·3	−0·4	0·5	−1·0	0·0	0·0	0·8	.....	**−0·1**			
	1·3	1·2	−0·9	−0·5	0·4	1·6	1·0	1·2	0·2	1·0	0·0	**0·5**	.....	**·009**	
379	4·6	.....	2·3	5·5	3·4	.....	.....	.....	.....	.....	.....	**4·5**			
	4·2	.....	2·9	3·3	4·1	.....	.....	.....	.....	.....	.....	**4·1**	4·1	**·046**	
380	5·2	.....	4·9	4·9	5·0	.....	.....	.....	.....	.....	.....	**4·5**			
	4·6	.....	4·8	3·6	6·0	.....	.....	.....	.....	.....	.....	**4·5**	.....	**·072**	
381	.....	.....	.....	0·7	.....	−0·1	−1·2	−0·1	1·4	−0·2	0·6	**0·0**			
	.....	−0·4	−1·1	−1·3	.....	0·4	−1·6	−1·1	−0·3	−0·7	−0·6	**−0·7**	.....	**·009**	
382	1·8	0·3	.....	0·7	.....	−0·9	2·6	2·6	1·3	−0·7	.....	**0·8**			
	1·0	−0·5	0·6	0·2	0·2	0·6	1·8	1·4	2·3	0·2	2·7	**0·9**	0·6	**·032**	−·057
383	.....	.....	.....	0·0	.....	2·3	−1·4	1·3	0·0	1·5	.....	**0·6**:			
	−0·3:	−0·4:	−2·2	−0·5	.....	.....	0·0	.....	.....	1·6	−1·3	**−0·4**:	.....	**·006**	
384	0·0	0·0	3·5	0·5	−0·4	0·8	−1·4	0·9	1·6	2·1	.....	**0·8**			
	.....	−0·4	2·5	3·8	0·1	0·3	−1·2	0·2	0·6	1·9	−0·5	**0·8**	1·3	**·017**	−·004

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
385	Boss 2528	.....	09 20·0	17 01	6·3	K0	·076	+ 0·8	2·5 0·4	2·2 2·8	....
386	Boss 2530	41 Lyncis	09 22·1	46 02	5·6	G5	·134	+37·5	1·5 2·0	1·0 1·2	....
387	Boss 2533	α Hydrae	09 22·7	−08 14	2·2	K5	·035	−15·8	−1·0	..... 0·5	....
388	Boss 2543	7 Leonis Min.	09 24·7	34 05	6·0	G8	·063	− 1·9	0·7 0·7	2·0 2·1	....
389	Boss 2549	24 Ursae Maj.	09 25·6	70 16	4·6	G2	·092	−21·5	3·2 4·3	3·4 2·7	2·8 4·1
390	Boss 2550	λ Leonis	09 26·1	23 25	4·5	K8	·053	+22·6	−1·2 0·0	....	....
391	Boss 2552	θ Ursae Maj.	09 26·2	52 08	3·3	F7	1·091	+17·1	2·3 2·9	3·2 3·0	0·6 2·5
392	Boss 2556	6 Leonis	09 26·5	10 09	5·3	K4	·022	+ 8·7	−1·3 −0·3	....	....
393	Boss 2566	10 Leonis Min.	09 28·1	36 51	4·6	G6	·029	−13·5	0·3 1·6	3·3 2·4	
394	H.R. 3804	.....	09 28·3	23 53	6·4	K7	.....	.....	.....	.....	.....
395	Boss 2573	11 Leonis Min.	09 29·7	36 16	5·5	G9	·748	+ 9·6	7·0 6·4	5·4 5·6	....
396	Boss 2578	.....	09 30·8	31 37	5·7	M2	·042	−25·9	.....	.....	.....
397	Boss 2583	9 Leonis	09 32·1	25 08	6·6	F8	·105	+21·9	4·5 2·9	2·4 3·4	4·3 3·8
398	Boss 2586	.....	09 32·6	14 48	6·6	F2	·116	+12·5	1·2 2·8	2·9 3·0	3·3 3·4
399	Boss 2589	2 Sextantis	09 33·2	05 06	4·8	K1	·171	+36·6	0·9 1·7	1·2 1·9	....
400	H.R. 3850	.....	09 35·7	31 43	6·1	K6	.....	.....	.....	.....	.....
401*	Boss 2602	ο Leonis	09 35·8	10 21	4·4†	F4	·147	+18·9	−2·2 −2·8	0·8 −0·2	0·8 1·7
402	Boss 2611	.....	09 38·2	64 07	6·5	F1*n*	·042	−27·9	0·6 1·6	2·5 2·0	0·3 1·6
403	Boss 2620	.....	09 40·3	45 35	6·8	K0	·153	−44·2	3·8 2·8	2·0 2·4	....
404	Boss 2621	.....	09 40·9	07 10	6·0	M2	·039	− 7·7	.....	.....	.....
405	Boss 2625	.....	09 42·1	21 05	7·8	F5	·315	.....	5·5 4·6	4·0 4·1	4·8 3·7
406	Boss 2626	.....	09 42·1	46 29	5·2	G0	·242	+ 4·7	5·3 5·2	3·1 3·4	5·7 5·5
407*	Boss 2632	υ Ursae Maj.	09 43·9	59 31	4·5†	A8	·329	+31·2	1·1 1·2	−0·1 2·0	0·6 0·2
408	Boss 2634	.....	09 44·2	21 39	6·0	F0	·046	+31·7	0·0 −0·1	0·9 1·8	−0·1 1·2

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
385	4·1	3·2	3·4	0·7	3·8	2·6	2·5	2·1	−0·3	3·4	.....	2·5			
	2·8	−0·3	3·4	4·7	3·4	1·2	1·4	1·3	3·2	4·7	.....	2·4	2·2	·017	·015
386	0·6	−0·5	0·6	−2·0	1·6	−0·7	.....	.....	.....	.....	.....	0·3			
	1·5	1·8	−0·8	−2·0	0·6	0·6	.....	.....	.....	.....	.....	0·6	.....	·009	
387	0·2	0·5	.....	−0·6	.....	−0·9	−0·7	−0·5	−1·4	−0·5	.....	−0·5			
	−0·8	−1·1	0·4	1·0	0·1	−0·4	−0·3	−0·7	0·2	0·8	0·4	0·0	0·1	·032	·004
388	−0·2	−0·5	1·0	0·7	−0·7	0·6	−0·6	−0·5	0·5	1·0	.....	0·3			
	0·0	−0·5	2·7	−0·9	1·8	1·5	−0·3	.....	2·4	2·4	.....	1·1	.....	·009	
389	1·8	.....	4·0	4·2	2·9	.....	.....	.....	.....	.....	.....	3·2			
	2·2	.....	3·4	3·3	4·4	.....	.....	.....	.....	.....	.....	3·5	2·0	·057	·048
390	1·2	0·3	.....	−1·8	.....	−0·5	−0·4	0·7	0·3	.....	.....	−0·2			
	0·2	−0·5	0·0	0·6	0·8	−0·2	−0·8	0·0	0·1	1·1	0·9	0·2	0·5	·012	·039
391	4·3	.....	0·4	2·0	1·8	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	3·0	2·6	2·0	.....	.....	.....	.....	.....	.....	2·7	3·0	·066	·073
392	0·5	0·0	.....	−1·0	.....	−0·8	−0·1	−1·0	−1·4	−1·6	.....	−0·7			
	0·6	−0·8	−1·0	0·1	0·9	1·0	0·0	0·4	−0·7	−1·2	−0·3	−0·1	0·5	·007	
393	1·9	1·0	3·5	3·6	1·0	1·1	1·3	0·5	−0·9	1·3	.....	1·5			
	3·5	.....	2·3	0·3	1·6	1·8	3·0:	2·4:	1·5	0·7	.....	1·9	0·7	·026	
394	.....	.....	.....	−0·3	.....	.....	−2·5	0·1	0·0	0·1	.....	−0·5:			
	0·3	−0·6	.....	.....	.....	.....	−1·6	−0·8	−1·3	0·4	−0·8	−0·6:	.....	·004	
395	5·9	3·9	6·8	7·8	7·4	.....	.....	.....	.....	.....	.....	6·3			
	5·2	4·4	5·7	4·8	8·0:	5·2	4·7	.....	5·0	.....	.....	5·5	5·4	·120	·104
396	.....	.....	.....	−0·6	.....	−3·7	0·4	0·1	−0·5	−0·9	−0·5	−0·8:			
	−0·8	−1·2	−4·0	−0·6	.....	.....	−0·5	−1·0	−1·1	−0·3	0·5	−1·0	.....	·005	
397	3·6	.....	4·9	3·9	2·5	.....	.....	.....	.....	.....	.....	3·7			
	2·9	.....	4·0	2·3	4·0	.....	.....	.....	.....	.....	.....	3·3	.....	·024	
398	.....	.....	2·8	3·4	2·6	.....	.....	.....	.....	.....	.....	2·7			
	.....	.....	0·3	2·2	2·2	.....	.....	.....	.....	.....	.....	2·3	.....	·015	
399	1·2	3·6	2·6	2·4	1·7	−0·5	2·8	0·7	−0·9	−0·4	.....	1·3			
	1·6	2·0	2·1	0·7	1·1	2·0	0·0	−0·4	−1·8	−1·0	.....	0·8	1·5	·018	
400	.....	.....	.....	−0·6	.....	.....	−1·8	−0·8	−1·4	−1·4	.....	−1·2:			
	−1·3	−1·9	.....	.....	.....	.....	−0·6	0·2	−1·8	−0·8	−1·0	−1·0	.....	·004	
401	....	.....	.....	1·0	−0·5	.....	.....	.....	.....	.....	.....	0·0			
	.....	.....	.....	3·0	0·4	.....	.....	.....	.....	.....	.....	0·4	−1·4	·014	·032
402	.....	.....	0·1	.....	3·3	.....	.....	.....	.....	.....	.....	1·3			
	.....	.....	1·6	.....	.....	.....	.....	.....	.....	.....	.....	1·7	.....	·010	
403	3·9	3·2	1·0	2·2	3·3	1·3	.....	.....	.....	.....	.....	2·6			
	2·6	3·8	1·5	0·0	2·2	1·5	.....	.....	.....	.....	.....	2·2	.....	·013	
404	.....	.....	.....	.....	.....	.....	−3·7	−1·9	0·0	−0·2	−0·5	−1·3:			
	.....	−0·1	.....	.....	.....	.....	−2·1	−0·7	−0·2	−0·2	−0·6	−0·6:	0·9	·004	
405	.....	.....	6·0	5·2	3·8	.....	.....	.....	.....	.....	.....	4·9			
	.....	.....	5·1	4·0	5·3	.....	.....	.....	.....	.....	.....	4·5	.....	·024	
406	4·6	.....	3·9	4·9	4·1	.....	.....	.....	.....	.....	.....	4·5			
	3·7	.....	3·8	3·6	3·6	.....	.....	.....	.....	.....	.....	4·1	.....	·066	
407	.....	.....	0·8	.....	.....	.....	.....	.....	.....	.....	.....	0·6:			
	.....	.....	1·6	.....	.....	.....	.....	.....	.....	.....	.....	1·2:	1·5	·019	
408	.....	.....	3·0	.....	0·2	.....	.....	.....	.....	.....	.....	0·8			
	.....	.....	2·2	1·3	0·7	.....	.....	.....	.....	.....	.....	1·2	.....	·010	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
409	Boss 2642	.....	09 46·3	24 52	5·3	A5	.....	.....	−0·1 0·7	1·6 2·1	3·0 2·7
410	Boss 2648	μ Leonis	09 47·1	26 29	4·1	K2	·225	+10·5	1·6 2·0	0·6 2·6	....
411	Boss 2656	.....	09 49·5	73 21	6·0	K1	·078	+ 8·2	0·4 1·5	0·0 1·1	....
412	Boss 2660	.....	09 50·2	57 54	6·0	G5	·066	−42·8	1·1 0·0	1·4 1·3	....
413	Boss 2662	18 Leonis Min.	09 50·7	32 51	6·6	F3	·037	+ 4·4	3·6 3·7	3·8 5·0	5·0 4·0
414	Boss 2665	19 Leonis Min.	09 51·6	41 32	5·2	F4	·114	− 6·2	3·5 4·6	1·7 2·0	5·3 5·6
415	Boss 2671	.....	09 52·9	08 48	6·3	K7	·034	−26·7	.....	.....	.....
416	Boss 2673	.....	09 53·0	57 18	5·7	M0	·051	−10·7	1·7	.....	.....
417	Boss 2680	π Leonis	09 54·9	08 31	4·9	M2	·041	+15·9	.....	.....	.....
418	Boss 2681	20 Leonis Min.	09 55·3	32 26	5·6	G7	·677	+53·8	4·8 5·2	4·8 5·2	....
419	.....	Groom. 1603	09 57·9	38 33	6·8	F7	·170	+26·4	3·8 4·2	3·1 2·2	4·4 4·4
420	.....	Groom. 1618	10 05·3	49 58	6·8	K6	1·451	−27·6	.....	.....	.....
421	Boss 2711	34 Leonis	10 06·2	13 51	6·4	F5	·069	−23·1	3·3 3·2	3·5 3·1	3·5 3·4
422	Boss 2727	24 Leonis Min.	10 10·8	29 10	6·5	G3	·105	+26·8	4·1 4·3	3·5 4·4	5·5 4·1
423	Boss 2728	35 Leonis	10 11·0	24 00	5·9	G3	·207	−40·5	1·9 2·6	4·4 3·3	5·1 3·7
424	Boss 2730	ζ Leonis	10 11·1	23 55	3·6	F1	·028	−16·2	0·8 0·4	1·5 0·9	0·7 −1·0
425	Boss 2734	39 Leonis	10 11·8	23 37	5·8	F7	·421	+35·5	4·3 4·3	4·9 4·3	3·6 2·4
426	Boss 2736	.....	10 12·8	44 33	6·7	G5	·309	− 5·4	4·6 4·4	5·6 5·3	....
427	Boss 2740	.....	10 14·1	54 43	6·2	K2	·021	+13·4	0·0 0·5	0·8 2·0	....
428	Boss 2741	40 Leonis	10 14·3	19 59	5·0	F6	·325	+ 3·0	2·5 2·8	3·1 3·5	3·9 3·7
429	Boss 2742	γ Leonis (br.)	10 14·5	20 21	2·6	G6	·341	−39·7	1·7 3·5	1·7 2·3	.....
430	Boss 2743	γ Leonis (ft.)	10 14·5	20 21	3·8	G5	·355	−39·7	1·3 3·5	1·5 1·6	....
431	Boss 2750	.....	10 16·3	41 44	5·9	F9	·191	− 6·3	2·3 3·2	2·5 2·4	4·5 3·6
432	Boss 2751	μ Ursae Maj.	10 16·4	42 00	3·2	K4	·083	−19·8	−0·8 0·7	.....	.....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
409	.....	.....	1·9	.....	.....	.....	.....	.....	.....	.....	.....	**1·6**			
	.....	.....	2·1	.....	.....	.....	.....	.....	.....	.....	.....	**1·9**	.....	**·019**	
410	1·0	0·1	.....	2·8	2·5	2·3	1·9	1·0	2·0	4·6	.....	**1·9**			
	0·3	0·5	3·2	1·7	1·4	1·8	2·4	1·6	2·3	4·4	3·0	**2·1**	0·6	**·038**	·025
411	0·5	0·8	.....	1·5	1·1	3·3	2·1	1·4	3·0	3·7	.....	**1·6**			
	1·4	0·5	2·3	2·5	1·8	2·1	1·4	.....	0·9	4·3	.....	**1·8**	0·4	**·014**	·001
412	1·9	1·2	−1·2	0·4	0·8	0·7	0·0	−0·1	0·8	2·7	.....	**0·8**			
	1·6	1·6	1·5	1·3	1·6	−0·1	−0·2	0·8	.....	0·7	.....	**0·9**	0·3	**·009**	·006
413	.....	.....	2·8	5·5	4·3	.....	.....	.....	.....	.....	.....	**4·2**			
	.....	.....	2·3	3·7	4·1	.....	.....	.....	.....	.....	.....	**4·0**	.....	**·032**	
414	4·1	.....	5·0	4·5	3·3	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	4·0	3·4	4·0	.....	.....	.....	.....	.....	.....	**3·9**	.....	**·056**	
415	.....	.....	.....	−1·2	.....	−1·8	−1·6	1·5	−0·1	−0·1	.....	**−0·5**			
	0·2	−0·5	−0·6	−0·4	1·5:	0·0:	0·6	0·6	−0·7	0·4	−0·2	**0·1**	0·6	**·005**	
416	.....	.....	.....	1·5	.....	1·9	0·6	1·6	1·9	1·0	1·4	**1·4**			
	.....	0·0	−0·7	1·0	.....	0·3	0·2	−0·2	0·4	0·2	0·4	**0·2**	.....	**·010**	
417	.....	.....	.....	0·0	.....	−2·2	−1·5	−1·0	0·5	0·2	0·0	**−0·6**			
	.....	0·0	−0·5	1·0	.....	−1·4	−1·7	−1·0	−0·2	−0·2	0·5	**−0·4**	−0·9	**·008**	
418	6·0	6·0	2·9	6·2	2·8	.....	.....	.....	.....	.....	.....	**4·8**			
	4·8	.....	4·0	6·5	3·4	.....	4·2	6·6	.....	.....	.....	**5·0**	5·3	**·072**	·063
419	4·3	.....	3·1	4·2	4·3	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	3·0	3·8	3·9	.....	.....	.....	.....	.....	.....	**3·6**	3·7	**·025**	·032
420	7·6	8·1	.....	.....	.....	.....	6·5	7·0	7·6	8·5	.....	**7·6**			
	7·7	8·2	8·9:	.....	7·6	7·7	7·2	8·1	9·2	8·7	8·2	**8·2**	8·3	**·166**	·177
421	3·7	4·7	4·0	.....	.....	.....	.....	.....	.....	.....	.....	**3·8**			
	2·5	3·9	3·9	.....	.....	.....	.....	.....	.....	.....	.....	**3·3**	.....	**·027**	
422	4·3	.....	2·4	3·3	3·7	.....	.....	.....	.....	.....	.....	**3·8**			
	4·2	5·1	2·9	2·5	3·2	4·9	.....	.....	.....	.....	.....	**4·0**	.....	**·030**	
423	4·9	.....	1·3	2·5	2·2	.....	.....	.....	.....	.....	.....	**3·2**			
	4·3	3·6	2·9	2·3	2·4	.....	.....	.....	.....	.....	.....	**3·1**	3·3	**·028**	·026
424	.....	.....	0·1	.....	0·0	.....	.....	.....	.....	.....	.....	**0·6**			
	.....	.....	1·8	−0·3	1·2	.....	.....	.....	.....	.....	.....	**0·5**	−0·1	**·025**	·010
425	3·4	.....	2·2	5·1	3·1	.....	.....	.....	.....	.....	.....	**3·8**			
	.....	.....	3·6	5·4	3·2	.....	.....	.....	.....	.....	.....	**3·9**	3·7	**·041**	·067
426	5·7	5·4	3·0	4·9	4·5	.....	.....	.....	.....	.....	.....	**4·8**			
	5·0	5·1	3·8	3·0	3·9	4·2	.....	.....	.....	.....	.....	**4·3**	.....	**·037**	
427	0·2	1·6	0·8	−1·2	0·0	0·8	−1·0	−0·5	−0·3	1·5	.....	**0·2**			
	0·4	−0·1	−0·9	−2·2	−0·3	1·5	1·1	2·2	0·0	0·1	0·1	**0·3**	.....	**·006**	
428	.....	.....	2·8	4·4	2·5	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	3·9	4·0	3·0	.....	.....	.....	.....	.....	.....	**3·5**	.....	**·047**	·052
429	0·3	0·7	1·4	0·8	−0·9	1·2	−1·0	−1·2	.....	.....	.....	**0·4**			
	0·9	0·3	3·1	0·8	0·3	1·2	−1·0	−0·9	.....	0·2	.....	**1·9**	0·8	**·042**	·000
430	0·6	1·6	0·8	3·3	1·5	−0·1	0·2	−0·3	−1·7	0·3	.....	**0·7**			
	0·3	0·9	0·9	2·5	0·8	0·5	1·3	1·9	.....	.....	.....	**1·4**	−0·2	**·028**	·000
431	3·7	.....	2·2	4·7	3·0	.....	.....	.....	.....	.....	.....	**3·3**			
	.....	.....	4·0	5·1	2·2	.....	.....	.....	.....	.....	.....	**3·4**	3·5	**·031**	·077
432	1·4	2·0	.....	3·0	.....	−0·6	0·7	2·0	−0·3	−0·5	.....	**0·8**			
	2·5	1·1	1·7	3·6	−0·7	−0·4	−1·4	−0·2	0·6	−1·6	−1·1	**0·4**	0·7	**·030**	·051

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
433	Boss 2761	28 Leonis Min.	10 18·4	34 13	5·8	K4	·027	−22·5	0·7 −0·1	....	....
434	Boss 2768	30 Leonis Min.	10 20·2	34 18	4·8	F1	·104	+13·6	0·8 2·1	1·3 2·7	3·0 1·0
435	Boss 2775	.....	10 21·9	49 19	6·5	G1	·896	− 4·1	4·8 5·4	5·4 5·2	5·0 5·4
436	Boss 2776	β Leonis Min.	10 22·1	37 13	4·4	G6	·159	+ 6·6	3·5 3·4	3·2 2·6	....
437	Boss 2780	.....	10 22·8	66 08	6·4	K2	·043	−18·9	1·3 1·1	0·8 2·0	....
438	Boss 2785	36 Ursae Maj.	10 24·2	56 30	4·8	F8	·181	+14·3	4·3 4·9	4·2 4·9	4·2 5·2
439	Boss 2800	46 Leonis	10 26·9	14 39	5·7	M2	·040	+30·0	....	....	....
440	Boss 2824	36 Leonis Min.	10 32·3	34 36	6·6	K3	·026	+17·3	....	....	....
441	Boss 2828	.....	10 32·9	54 12	5·7	K2	·116	+49·7	0·3 0·2	..... 0·9	....
442	Boss 2829	37 Leonis Min.	10 33·1	32 30	4·8	F9	·010	− 7·0	−1·5 −1·4	−1·0 −0·6	−0·4 −0·1
443	Boss 2831	38 Leonis Min.	10 33·4	38 26	5·8	G0	·223	+17:	1·2 0·9	1·2 1·8	5·7 5·0
444	Boss 2838	.....	10 34·7	68 58	5·9	K4	·036	+13·1	0·4 1·2	....	....
445	Boss 2847	.....	10 36·6	32 14	6·3	M5	·028	+14·4	−1·8 −1·5	....	....
446	Boss 2853	.....	10 37·7	46 44	5·3	A9	·286	+ 6·3	1·9 1·9	2·3 3·1	1·8 1·0
447	Boss 2858	35 Sextantis	10 38·1	05 16	6·0	K5	·045	− 8·3	....	....	....
448	Boss 2864	36 Sextantis	10 40·0	03 00	6·6	K2	·051	+ 4·0	..... −0·3	..... −2·2	....
449	Boss 2865	.....	10 40·2	57 53	6·5	M2	·079	+ 4·3	....	....	....
450	Boss 2895	.....	10 46·5	53 06	6·7	G9	·021	− 8·1	0·9 1·0	0·5 2·2	....
451	Boss 2896	.....	10 46·5	53 03	6·6	K1	·088	−1·9	1·6 1·6	1·2 1·8	....
452	Boss 2897	.....	10 46·7	70 23	6·1	K0	·404	+24·7	5·2 4·5	2·5 2·6	....
453	Boss 2899	46 Leonis Min.	10 47·7	34 45	3·9	K1	·303	+17·8	0·5 1·9	1·0 1·2:	....
454	Boss 2910	.....	10 50·2	34 02	5·2	K1	·112	−22·1	2·3 1·8	0·0 2·0	....
455	Boss 2912	.....	10 50·6	42 33	6·1	K2	·099	−51·0	1·2 −0·4	2·2 2·4	....
456	Boss 2913	55 Leonis	10 50·6	01 16	6·0	F2	·105	− 2·7	3·2 2·9	3·4 3·0	4·2 2·2

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π	
433	−0·5	0·0	0·3	−1·0	.....	0·8	−0·3	−0·8	−1·2	−1·7	.....	−0·4	.....	·005		
	.....	.....	−1 1	−0·4	−0·4	2·0	−1·4	.....	−1·5	−1·5	−1·0	−0·6				
434	.....	.....	2 3	1·8	2·1	.....	.....	.....	.....	.....	.....	1·9	.....	·028		
	.....	.....	2·7	2·1	2·1	.....	.....	.....	.....	.....	.....	2·1				
435	5·6	.....	2·5	5·4	5·7	.....	.....	.....	.....	.....	.....	4·9	5·6	·048	·078	
	5·3	.....	3·2	4·2	5·8	.....	.....	.....	.....	.....	.....	4·9				
436	1·0	−0·2	3·7	1·9	0·6	1·8	0·5	1 6	2·0	2·4	.....	1·8	1·2	·030	·013	
	0·8	0·4	3·5	4·0	2·3	1·5	−0·2	−0·6	.....	.....	.....	1·8				
437	1·1	1·4	1·7	−1·6	−1·3	0·8	−0·3	−0·4	−1·2	1·6	.....	0·3	1·0	·007		
	0·9	1·2	−0·4	−1·6	0·7	1·4	1·9	.....	−0·3	2·4	−0·5	0·7				
438	4·6	.....	4·5	5·3	3·8	.....	.....	.....	.....	.....	.....	4·4	3·6	·083	·091	
	3·6	.....	4·2	4·3	3·8	.....	.....	.....	.....	.....	.....	4·4				
439	.....	.....	.....	.....	.....	.....	−0·4	−2·5	−0·6	−1·2	−1·0	−1·2:	1·0	·004	·005	
	−1·0	−1·2	.....	.....	.....	.....	−0·9	−1·2	−1·2	−1·3	−1·3	−1·2:				
440	0·8	.....	.....	−0·8	.....	.....	−2·6	−1·3	−1·1	0·4	.....	−0·8:	.....	·004		
	.....	0·2	−2·2	−2·2	.....	.....	−1·3	0·0	0·2	0·5	−0·3	−0·6				
441	3·0	2·2	0·9	0·8	.....	2·3	1·0	0·0	−0·9	−0·4	.....	0·9	.....	·010		
	2·3	1·3	−1·7	−1·0	.....	2·5	2·9	0·8	−1·4	−0·4	−0·2	0·5				
442	.....	.....	−2·6	1·5	−1·4	.....	.....	.....	.....	.....	.....	−0·9	.....	·008		
	.....	.....	−1·4	−0·4	0·8	.....	.....	.....	.....	.....	.....	−0·5				
443	2·5	.....	2·2	5·1	4·0	.....	.....	.....	.....	.....	.....	3·1	2·2	·028	·029	
	2·1	.....	3·4	4·3	3·6	.....	.....	.....	.....	.....	.....	3·0				
444	0·3	0·0	.....	−0·7	.....	1·1	−1·1	0·6	0·5	−0·2	.....	0·0	.....	·007		
	2·2	0·6	−1·8	−1·4	−0·5	0·6	−0·3	1·2	−0·7	−0·6	−1·1	0·0				
445	.....	.....	.....	−1·6	.....	−0·8	−1·7	−0·9	−0·8	−1·2	−2·1	−1·5	.....	·003		
	−0·8	−0·7	.....	−1·7	.....	−2·2	−1·8	−0·9	−2·2	−1·0	−1·9	−1·5				
446	.....	.....	1·7	.....	1·1	.....	.....	.....	.....	.....	.....	1·8	1·6	·020	·031	
	.....	.....	2·0	1·9	1·2	.....	.....	.....	.....	.....	.....	1·8				
447	.....	.....	.....	−1·4	.....	.....	−1·1	0·3	−0·3	0·4	.....	−0·4:	.....	·005		
	.....	−0·8	−1·2	−2·1	.....	.....	0·3	0·2	−0·2	0·6	0·2	−0·4				
448	.....	.....	.....	−1·5	.....	.....	−2·2	−1·0	0·0	1·2	.....	−0·7:	.....	·004		
	.....	−2·5	−1·4	−0·8	.....	1·1	1·0	1·3	−0·5	1·3	−0·6	−0·3				
449	.....	.....	.....	−0·4	.....	−0·3	−1·4	−2·5	0·4	0·1	−0·1	−0·6	1·0	·003		
	.....	−0·1	−2·0	.....	.....	−1·4	−0·9	−1·0	−2·2	−0·3	−0·9	−1·1				
450	1·0	0·6	1·0	−1·0	−1·7	1·0	0·8	1·0	−0·2	2·1	.....	0·5	.....	·006		
	0·4	0·2	1·1	−0·9	0·2	1·1	−0·7	1·3	1·0	1·8	.....	0·7				
451	0·7	0·6	0·0	−0·9	−0·7	0·1	0·1	0·1	0·1	0·8	.....	0·3	.....	·006		
	1·0	1·5	−1·3	−2·7	−0·2	1·5	2·4	1·4	0·0	0·6	.....	0·6				
452	3·9	3·2	3·6	2·6	1·7	5·0	3·7	4·2	2·4	3·0	.....	3·4	4·3	·028	·011	
	1·8	3·3	5·4	3·1	2·7	.....	3·0	4·2	.....	2·4	.....	3·3				
453	2·8	3·4	3·4	2·0	1·1	1·0	2·9	2·8	0·8	1·3	.....	1·9	1·4	·039	·058	
	1·7	2·5	2·5	3·3	2·8	1·6	1·9	1·4	0·2	0·1	.....	1·8				
454	0·9	1·4	3·2	1·0	1·5	2·2	−0·4	0·3	1·0	−0·2	.....	1·1	0·7	·013	·014	
	0·8	0·5	0·6	0·3	0·6	0·8	−0·4	0·8	−0·3	−0·4	.....	0·6				
455	1·5	1·6	0·8	−0·4	−0·7	−0·5	1·4	0·0	0·0	0·9	.....	0·7	3·0	·009		
	2·4	1·0	−1·1	0·4	0·4	1·6	2·4	1·1	0·9	1·3	0·5	1·0				
456	.....	.....	4·4	1·5	2·3	.....	.....	.....	.....	.....	.....	3·2	.....	·023		
	4·3	.....	0·7	2·4	1·2	.....	.....	.....	.....	.....	.....	2·4				

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
457	Boss 2918	.....	10 52·0	78 18	6·3	G4	·080	−41·5	1·8	1·3 1·0	.... 0·7
458	Boss 2920	47 Ursae Maj.	10 53·9	40 58	5·1	G1	·321	+13·9	4·0 4·2	4·7 4·7	6·0 5·7
459	Boss 2921	.....	10 53·9	36 40	6·2	M4	·096	−31·1	−0·4	.....	....
460	Boss 2924	.....	10 54·7	43 27	6·1	F7	·176	− 3·1	2·8 3·2	2·0 3·0	4·3 4·1
461	Boss 2933	α Ursae Maj.	10 57·6	62 17	2·0	G4	·137	− 1·3	0·8 1·8	0·8 0·4	0·8 1·6
462	Boss 2942	χ Leonis	10 59·9	07 53	4·7	F6	·346	+ 2·9	−0·9 −0·1	2·6 1·3	−0·4 −1·2
463	Boss 2951	.....	11 02·3	23 52	6·4	A2	.....	.....	2·0 2·7	2·1 3·3	3·5 3·0
464	Boss 2953	.....	11 02·5	86 11	7·2	A3	·031	+ 3·3	−0·2 −1·2	−1·2 −2·0	−0·3 −1·4
465	Boss 2958	ψ Ursae Maj.	11 04·0	45 02	3·1	K0	·067	+ 0·8	0·6 3·4	0·0 1·8	....
466	H.R. 4336	.....	11 04·0	43 45	6·0	M2	.....	.....	.....	.....	.....
467	H.R. 4345	.....	11 07·1	36 21	6·3	F9	.....	.....	6·2 5·6	5·0 6·0	4·2 5·1
468	Boss 2967	.....	11 08·5	20 41	6·9	G4	·406	+44·2	3·4 3·4	4·4 4·2	2·5 1·0:
469	Boss 2973	.....	11 08·8	08 37	5·9	K1	·129	+13·5	0·8 1·4	0·7 2·5	.....
470	Boss 2977	.....	11 10·3	53 19	6·3	F3	·177	−37·6	4·3 4·7	3·8 3·3	6·0 4·7
471	Boss 2978	73 Leonis	11 10·6	13 51	5·5	K1	·025	+10·2	0·6 1·9	2·1 3·0	....
472	Boss 2980	Groom. 1757	11 11·1	50 01	6·0	G9	·089	+ 4·2	0·8 −0·8	1·7	.....
473	Boss 2984	ξ Ursae Maj. (br.)	11 12·9	32 06	4·4	F8	·730	−13·6	4·9 5·0	4·7 4·9	4·5 5·6
474	Boss 2984	ξ Ursae Maj. (ft.)	11 12·9	32 06	4·9	G2	·729	−13·8	4·3 5·1	5·0 5·1	5·4 3·7
475	Boss 2999	ι Leonis	11 18·7	11 05	4·0	F4	·177	−10·2	0·2 1·4	2·0 1·6	2·2 1·7
476	Boss 3000	.....	11 18·9	01 58	5·5	G5	·029	−12·5	1·4 1·0	0·6 1·7	....
477	Boss 3007	.....	11 20·4	56 24	5·8	G9	·073	0·0	0·1 1·1	0·4 2·2	.....
478	Boss 3008	81 Leonis	11 20·4	17 01	5·6	F2	·142	+15·6	1·0 2·4	1·3 2·0	2·2 2·2
479	Boss 3014	83 Leonis (br.)	11 21·7	03 33	6·5	G8	·739	+ 0·2	4·9 4·6	4·3 4·5	....
480	Boss 3207	.....	11 24·9	81 41	6·1	A2	·148	+11·7	0·5 −0·1	1·7 2·6	2·7 2·2

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
457	1·3	.....	0·1	2·5	0·2	−0·1	.....	.....	.....	.....	.....	**1·0**			
	0·4	0·3	0·2	0·6	0·4	−0·2	.....	.....	.....	−0·1	.....	**0·4**	0·5	**·008**	
458	5·3	.....	2·9	4·4	3·6	.....	.....	.....	.....	.....	.....	**4·4**			
	3·8	.....	3·6	4·4	3·6	.....	.....	.....	.....	.....	.....	**4·3**	4·1	**·070**	·080
459	.....	.....	.....	−0·2	.....	0·9	−2·0	−0·1	1·1	−0·8	−1·2	**−0·4:**			
	.....	0·0	0·3	0·1	.....	−1·2	.....	.....	−0·2	−1·2	−0·4	**−0·3:**	1·0	**·005**	
460	4·2	.....	2·8	4·4	2·2	.....	.....	.....	.....	.....	.....	**3·2**			
	5·2	.....	1·9	1·0	1·7	.....	.....	.....	.....	.....	.....	**2·9**	.....	**·025**	
461	0·0	0·0	3·2	2·1	1·0	.....	.....	.....	.....	.....	.....	**1·1**			
	1·0	0·1	3·3	2·1	.....	.....	.....	.....	.....	.....	.....	**1·6**	0·4	**·074**	·037
462	.....	.....	0·1	−1·3	0·5	.....	.....	.....	.....	.....	.....	**0·1**			
	.....	.....	0·9	0·4	0·0	.....	.....	.....	.....	.....	.....	**0·2**	0·8	**·012**	·012
463	.....	.....	3·0	.....	.....	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	2·5	.....	.....	.....	.....	.....	.....	.....	.....	**2·9**	.....	**·019**	
464	.....	.....	.....	.....	+0·6	.....	.....	.....	.....	.....	.....	**−0·3**			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**−1·5**	.....	**·002**	
465	2·2	1·8	1·7	1·1	0·8	2·2	−0·2	1·0	0·0	1·7	.....	**1·1**			
	1·8	0·5	2·5	2·3	4·1	4·0	0·0	1·3	0·6	2·1	.....	**2·0**	1·3	**·049**	
466	.....	.....	.....	−1·6	.....	−2·3	−1·1	−0·4	0·7	0·0	.....	**−0·8**			
	.....	0·2	.....	−2·8:	.....	−1·4	−1·5	−0·7	−2·2	−0·8	−0·5	**−1·1**	.....	**·004**	
467	5·7	.....	6·5	5·8	4·8	.....	.....	.....	.....	.....	.....	**5·5**			
	5·2	.....	5·5	4·3	4·7	.....	.....	.....	.....	.....	.....	**5·2**	.....	**·064**	
468	5·6	3·3	1·8	1·3	3·8	.....	.....	.....	.....	.....	.....	**3·3**			
	5·1	3·4	1·2	.....	.....	4·8	.....	.....	.....	.....	.....	**3·3**	.....	**·019**	
469	1·5	1·8	−0·5	−0·2	−0·5	−0·2	0·0	1·3	0·2	1·5	.....	**0·5**			
	1·0	0·8	−0·9	−1·2	0·4	1·0	1·4	3·1:	0·2	1·4	.....	**0·9**	.....	**·009**	
470	.....	.....	5·1	4·2	3·5	.....	.....	.....	.....	.....	.....	**4·5**			
	.....	.....	2·0	3·2	3·7	.....	.....	.....	.....	.....	.....	**3·6**	.....	**·035**	
471	0·3	0·5	0·8	0·5	−1·0	0·8	−0·7	1·1	−0·3	−0·4	.....	**0·4**			
	1·0	0·8	0·4	−1·0	−1·7	0·8	1·1	.....	0·2	0·1	.....	**0·6**	1·0	**·010**	
472	1·3	0·5	1·8	0·7	2·8	−0·2	2·4	2·3	0·5	1·9	.....	**1·4**			
	0·6	0·8	3·7	3·7	.....	−0·3	2·2	1·9	.....	2·8	.....	**1·6**	1·4	**·012**	−·081
473	5·3	.....	5·5	5·9	5·5	.....	.....	.....	.....	.....	.....	**5·2**			
	4·7	.....	5·4	5·4	4·5	.....	.....	.....	.....	.....	.....	**5·1**	4·9	**·141**	·158
474	6·1	.....	.....	6·1	3·2	.....	.....	.....	.....	.....	.....	**5·0**			
	4·7	.....	4·3	5·5	3·0	.....	.....	.....	.....	.....	.....	**4·5:**	5·3	**·093**	·158
475	.....	.....	2·8	4·3	3·0							**2·4**			
	.....	.....	3·1	3·6	3·2	.....	.....	.....	.....	.....	.....	**2·4**	2·8	**·048**	
476	−0·7	1·6	0·1	1·5	0·0	0·6	.....	−0·2	−0·2	1·7	.....	**0·6**			
	1·0	0·0	0·6	−0·6	0·5	−0·3	−0·6	.....	0·9	0·7	.....	**0·4**	.....	**·010**	
477	1·1	2·3	−0·5	0·5	−0·4	0·0	0·6	0·0	−1·4	0·1	.....	**0·2**			
	1·6	1·8	−2·2	−1·1	0·8	0·0	1·4	.....	0·2	−1·1	.....	**0·4**	.....	**·008**	
478	.....	.....	2·2	4·0	3·0	.....	.....	.....	.....	.....	.....	**2·4**			
	.....	.....	0·1	1·8	2·4	.....	.....	.....	.....	.....	.....	**1·8**	.....	**·020**	
479	5·1	4·3	3·7	4·3	5·1	.....	.....	.....	.....	.....	.....	**4·5**			
	3·4	3·7	3·7	5·2	6·2	.....	.....	.....	.....	.....	.....	**4·5**	5·3	**·040**	·023
480	.....	.....	.....	.....	0·5	.....	.....	.....	.....	.....	.....	**1·3**			
	.....	.....	3·2	2·1	0·6	.....	.....	.....	.....	.....	.....	**1·8**	.....	**·012**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
481	Boss 3030	86 Leonis	11 25·3	18 58	5·7	K0	·076	+25·9	2·2 1·8	1·4 2·2	....
482	Boss 3031	λ Draconis	11 25·5	69 53	4·1	K5	·043	+15·4	−1·1 −1·0	....	....
483	Boss 3033	Bu. 5811	11 26·7	61 38	5·8†	F7	·077	−40·9	4·2 4·7	4·0 4·2	3·5 3·4
484	H.R. 4452	.....	11 28·6	37 23	6·3	K1 ..	.....	.....	3·0 3·0	..... 2·2	....
485	H.R. 4454	.....	11 29·0	11 35	6·5	A2 ..	.....	.....	0·8 0·8	1·7 3·0	3·9 2·9
486	Boss 3058	υ Leonis	11 31·8	−00 16	4·5	K1	·037	− 0·2	0·8 2·4	0·0 2·1	....
487	Boss 3069	Bu. 5858 (br.)	11 33·5	45 40	6·3	F9	·579	−11·8	4·6 5·1	4·6 5·5	4·9 5·2
488	Boss 3075	61 Ursae Maj.	11 35·7	34 46	5·5	G6	·388	− 2·7	5·6 5·7	5·7 6·0	....
489	Boss 3078	62 Ursae Maj.	11 36·4	32 18	5·7	F3	·344	+34·1	3·6 3·6	3·8 4·5	4·0 3·2
490	Boss 3083	.....	11 38·3	42 17	6·8	G5	·031	+ 7·3	2·6 1·0	1·0 2·3	....
491	Boss 3089	ν Virginis	11 40·7	07 05	4·2	M0	·185	+51·0	−0·6 −0·4	... .	....
492	Boss 3090	χ Ursae Maj.	11 40·8	48 20	3·8	K0	·134	−2·2	2·8 2·6	0·7 1·8	....
493	Boss 3098	93 Leonis	11 42·8	20 46	4·5	F4	·152	+ 2·3	4·2 3·5	2·5 2·0	3·3 3·7
494	H.R. 4535	.....	11 44·1	16 48	6·0	A3 ..	.....	.....	0·4 0·7	1·2 1·8	3·6 1·8
495	Boss 3102	.....	11 44·5	35 29	5·8	F5	·115	.....	2·1 1·8	1·0 1·6	3·2 1·8
496	Boss 3105	β Virginis	11 45·5	02 20	3·8	F8	·795	+ 4·0	4·1 3·7	3·3 2·3	4·3 5·2
497	H.R. 4545	.....	11 46·0	33 56	6·6†	A + F..	.....	.....	0·4 0·3	1·0 1·3	1·6 0·8
498	Boss 3112	Groom. 1830	11 47·2	38 26	6·5	G7	7·046	−91·5	6·6 5·2	7·2 6·8	....
499	Boss 3137	.....	11 55·6	−09 52	5·6	G9	·490	− 2·1	2·9 2·9	3·6 4·0	....
500	Boss 3141	.....	11 56·5	36 36	5·6	G8	·133	+33·5	0·8 0·2	2·0 1·5	....
501	Boss 3142	1 Comae Ber.	11 56·6	22 39	6·6	F7	·040	+13·4	4·7 2·6	1·3 1·5	−0·2 0·5
502	Boss 3143	67 Ursae Maj.	11 57·1	43 36	5·1	A3	·321	+15·1	1·1 2·6	2·4	1·6 3·1
503	Boss 3149	.....	11 58·7	06 08	6·5	F5	·167	+ 8·5	1·4 1·9	2·0 3·0	3·2 1·4
504	Boss 3155	ο Virginis	12 00·1	09 18	4·2	G6	·219	−27·6	1·2 −2·2	0·2 1·2	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
481	2·2	1·8	1·2	−1·2	−0·6	0·8	1·1	1·2	0·2	1·0	.....	**0·9**			
	1·2	1·7	1·9	0·8	1·0	0·0	0·0	0·7	−0·7	1·2	.....	**1·0**	1·1	·011	·009
482	1·8	0·0	.....	1·7	.....	−0·8	−0·7	−2·2	−2·3	−2·9	.....	**−0·7**			
	−1·1	−2·4	−0·4	1·2	−1·3	−1·4	0·3	−0·6	−1·0	−2·2	−0·8	**−0·9**	0·2	·010	·018
483	4·7	.....	5·5	5·5	2·7	.....	.....	.....	.....	.....	.....	**4·3**			
	4·8	.....	5·5	4·9	3·9	.....	.....	.....	.....	.....	.....	**4·5**	4·0	·053	·057
484	1·0	1·4	0·2	0·1	0·4	2·2	1·6	1·8	0·2	0·9	.....	**1·2**			
	1·7	0·8	−1·3	−1·2	1·8	1·5	2·4	1·4	−1·2:	0·5	.....	**1·0**	.....	·009	
485	.....	.....	.....	.....	1·4	.....	.....	.....	.....	.....	.....	**2·0:**			
	.....	.....	2·9	2·3	1·7:	.....	.....	.....	.....	.....	.....	**2·4:**	.....	·014	
486	5·1	4·0	0·2	0·6	1·7	2·2	0·6	0·1	−0·9	0·0	.....	**1·2**			
	3·6	3·3	−0·4	1·2	0·7	2·6	1·1	1·7	.....	0·0	.....	**1·7**	1·0	·025	
487	4·2	3·7	4·6	4·9	.....	.....	.....	.....	.....	.....	.....	**4·5**			
	3·5	4·0	4·0	3·8	.....	.....	.....	.....	.....	.....	.....	**4·4**	4·1	·043	·038
448	6·5	6·0	4·7	6·0	4·5	.....	.....	.....	.....	.....	.....	**5·6**			
	6·2	5·9	6·4	7·3	2·8	4·6	6·2	6·4	.....	.....	.....	**5·8**	4·8	·110	·072
489	.....	.....	2·1	3·2	3·9	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	2·3	2·3	3·4	.....	.....	.....	.....	.....	.....	**3·2**	3·8	·033	·042
490	0·6	0·8	1·3	−0·7	−1·3	−0·4	.....	−1·8	−2·1	0·8	.....	**0·2**			
	1·1	0·2	−0·6	−2·0	−0·2	−1·3:	0·5	.....	−0·8	0·0	.....	**0·0**	.....	·005	
491	.....	.....	.....	0·5	.....	−1·0	2·3	2·6	−1·1	−1·5	−1·3	**0·0**			
	.....	.....	0·0	1·0	.....	−0·2	1·5	0·8	−1·2	−1·0	−0·4	**0·0**	0·2	·014	
492	−0·3	0·8	0·4	−0·4	2·2	1·9	−1·3	−1·4	−1·2	−0·5	.....	**0·3**			
	0·6	0·5	−0·3	−2·8	2·0	2·2	−1·2	−0·7	−1·2	−0·8	.....	**0·2**	1·3	·019	
493	.....	.....	4·2	1·7	3·1	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	2·8	2·0	2·5	.....	.....	.....	.....	.....	.....	**2·8**	3·1	·050	·029
494	.....	.....	.....	.....	0·2	.....	.....	.....	.....	.....	.....	**1·4:**			
	.....	.....	3·2	1·7	0·3	.....	.....	.....	.....	.....	.....	**1·6:**	.....	·012	
495	.....	.....	0·0	3·5	2·8	.....	.....	.....	.....	.....	.....	**2·1**			
	.....	.....	0·9	2·2	2·2	.....	.....	.....	.....	.....	.....	**1·8**	.....	·017	
496	3·7	.....	2·7	4·5	4·0	.....	.....	.....	.....	.....	.....	**3·8**			
	.....	.....	2·7	3·7	4·1	.....	.....	.....	.....	.....	.....	**3·6**	3·5	·096	·104
497	.....	.....	.....	.....	2·3	.....	.....	.....	.....	.....	.....	**1·3:**			
	.....	.....	0·9	1·6	0·0	.....	.....	.....	.....	.....	.....	**0·8:**	.....	·008	
498	7·5	6·5	5·7	6·9	7·8	.....	.....	.....	.....	.....	.....	**6·9**			
	6·7	6·4	8·2	7·6	5·1	4·9	8·4	4·8	.....	.....	.....	**6·4**	6·0	·108	·106
499	6·2	2·5	2·8	2·6	4·1	.....	.....	.....	.....	.....	.....	**3·5**			
	5·6	2·1	3·2	3·1	3·4	5·8	5·4	5·0	5·2	5·1	.....	**4·2**	4·8	·044	·101
500	2·4	2·4	0·5	0·4	1·8	0·7	1·6	1·6	0·8	1·1	.....	**1·3**			
	2·6	2·3	2·2	2·6	2·3	0·3	2·2	1·8	−0·3	0·3	.....	**1·5**	0·9	·014	·036
501	4·5	.....	1·0	0·4	3·2	.....	.....	.....	.....	.....	.....	**2·1**			
	3·6	.....	−1·1	−1·2	2·9	.....	.....	.....	.....	.....	.....	**1·3**	.....	·016	
502	.....	.....	4·1	5·0	0·2	.....	.....	.....	.....	.....	.....	**2·4**			
	.....	.....	2·9	3·1	1·2	.....	.....	.....	.....	.....	.....	**2·6**	.....	·030	·011
503	4·5	.....	1·3	−0·5	2·6	.....	.....	.....	.....	.....	.....	**2·1**			
	.....	.....	2·0	0·4	2·2	.....	.....	.....	.....	.....	.....	**1·8**	.....	·012	
504	2·6	1·6	−0·8	−0·3	−0·7	−1·0	0·2	−1·2	−2·0	−1·9	.....	**−0·2**			
	2·0	1·4	−1·1	−2·3	0·2	−3·4	−0·4	−0·4	0·2	−1·0	.....	**−0·5**	0·4	·012	·039

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
505	Boss 3156	.....	12 00·2	77 28	6·0	K0	·169	− 8·9	0·6 −0·2	0·0 0·0	....
506	Boss 3157	.....	12 00·6	63 30	6·2	K1	·085	−16·4	0·0 0·6	2·7 3·2	....
507	Boss 3171	.....	12 05·0	06 22	5·7	F4	·163	+ 6·4	0·4 0·9	2·8 3·0	0·3 0·0
508	Boss 3180	.....	12 06·7	26 25	5·8	K4	·059	+29·9	....	....	....
509	Boss 3181	.....	12 07·1	21 06	5·7	G5	·031	−21·7	2·0 2·8	2·5 1·8	....
510	Boss 3189	.....	12 10·4	70 45	5·9	K3	·040	− 6·5	−1·0 0·4	−0·8 0·6	....
511	Boss 3198	.....	12 12·5	29 30	5·7	A2	·053	− 1·8	0·7 1·1	1·4 2·6	3·9 2·8
512	H.R. 4672	.....	12 12·5	53 45	6·0	K6	.....	.....	0·3 1·6	....	....
513	Boss 3209	9 Comae Ber.	12 14·5	28 43	6·3	F8	·241	− 5·4	2·4 3·4	3·4 2·7	4·6 4·8
514	Boss 3213	16 Virginis	12 15·3	03 53	5·1	K0	·304	+37·4	2·1 1·6	2·0 2·2	....
515	Boss 3216	11 Comae Ber.	12 15·6	18 21	4·9	G8	·138	+49·7	2·0 2·8	0·0 0·5	....
516*	H.R. 4698	preceding	12 15·7	27 37	7·0†	F2	.....	.....	....	1·2 2·3	3·0 3·8
517*	H.R. 4698	following	12 15·7	27 37	7·0†	F2	.....	.....	..... 4·0	2·5 3·6	1·6 2·8
518	Boss 3219	70 Ursae Maj.	12 16·1	58 25	5·7	K7	·082	−34·9	0·6 0·7	....	....
519	Boss 3224	12 Comae Ber.	12 17·5	26 24	5·3†	A + F	·013	− 4·4	3·7	0·6 2·0	4·8 5·1
520	Boss 3230	5 Can. Ven.	12 19·2	52 07	5·0	G6	·014	− 3·2	−0·9 −0·8	..... 0·0	....
521	Boss 3233	.....	12 20·2	24 29	6·1	G9	·072	− 0·7	3·0 1·4	1·2	....
522	Boss 3235	6 Can. Ven.	12 20·9	39 34	5·2	G8	·083	+ 3·6	1·1 1·6	1·9 1·6	....
523	Boss 3242	γ Comae Ber.	12 22·0	28 49	4·6	K1	·120	+10·2	1·3 1·1	1·4 2·2	....
524	Boss 3267	.....	12 26·1	53 37	6·2	G0	·177	−14·3	2·8 3·4	3·9 4·6	4·9 3·7
525	Boss 3278	.....	12 28·7	33 48	5·4	G8	·039	−13·3	3·1 1·9	2·1 2·1	....
526	Boss 3279	β Can. Ven.	12 29·0	41 54	4·3	G0	·755	+16·2	4·7 4·8	5·0 5·4	4·8 4·7
527	Boss 3299	26 Comae Ber.	12 34·2	21 36	5·5	G7	·074	−19·0	1·3 1·9	2·1 2·1	....
528	Boss 3307	γ Virginis n.p.	12 36·6	−00 54	3·6	F3	·561	−17·5	3·1 2·8	2·5 1·9	3·2 2·5

No.															
505	1·0	2 1 0 2	0 5 −3 2	−1 2 −1 6	0 2 −3 4	0 5 0 6	−1·2 0 5	−0 1 1·3	−1·4 −2·5	−1 3 0 1		−0 1 −0 5		006	
506	2 5 1 0	1 1 . .	0 1 −0 3	−1 3 −1 1	0 2 0 2	0 3 0 4	0 0 . .	0·4 . .	−1·6 −1·2	−0·9 0·8	. .	0 3 0 7	1 4	007	
507			3·6 2·2	2 2 2 5	1 1 1 3							1 8 1 6		016	
508	0 0	0 2 −2·1	. . . . .				−2 1 . .	−5 2 . .	0 7 2 1	−0 1 0 0	−0·5	−0 4 0 0		006	
509	1 0 1·3	1 0 −0·4	1·1 0·9	2 7 −0·8	0·5 0·0	0·4	. . . . .	. . . . .	. . . . .	0·7		1 4 0 8		012	
510	0 1 0 2	0 3 1·6	−0 1 −2 5	−1 1 −3 4	1 1 0 6	1 0 0 6	−0 4 1 6	−1 2 −1 5	−1 0 0 6	1 7		−0 4 0 3		·006	
511	. . . . .	. . . . .	2·9	2·8	3·2 3·0	. . . . .	. . . . .					2 3 2·5		·022	
512	0 1 2 3	0 4 1·2	−0·8	−0 2 −0 2	1 0	−0 3 1·7	−0 1 1 6	1 2 1 2	0 4 −1 0	1·2 1 0	0·7	0 5 1·0		·009	
513	5·4 2·5		2·9 3·3	3·9 4·6	3·3 4·0	. . . . .						3·6 3·6	3·4	·029	·054
514	1·0 1·0	2·5 2·4	0·5 −1·3	−0·6 −1·5	−0·9	0 1 −0 3	1 7 1 4	0 3 0 1	−1 7 0 2	−0 2 −1 0		0 6 0·4	1·6	·012	−·006
515	0 1 . .		1 1 0 1	0 2 0 1	2 1 3 0	0 0 1 4	3 0				1·2	1·8 1·9	0·7	·025	
516			1 0 −0·5	3·1	1·4	. . . . .						1·7 : 2·2		·010	
517	. . . . .	. . . . .	3·2 −0·4	−0·8	3 1 2 8							2·6 : 2·0 :		·012	
518	1 3 1 2	0 5	−0 2 . .	−1 3 −1 0	0 6	0 2 0 6	−0 0 1 3	−0 0 2 2	−1·7 −1 1	−1·1 0·2	0·0	−0·5 0·3		·007	
519	1 0		2 2 1 6	1 0 1 1	3 1 3 7							3·1 : 3·1		·036	
520		1 1 0 3	1 2 1 1	1 3 1 1	−1 3 1 4	0 7 1 3	1 2 0 3	−0 2 −0 4	−2·0 0 0	0·1 0 0		−0·1 0·5	0·1	·011	
521	1 3 1 1	1 7 0 9	−1 1 −0 9	0 1 0 2	−1 3 1 3	1 3 0 1	0 3 0 3	1 2	0·1 2·4			0·7 0·4	0·6	·008	·005
522	2 2 2 1	2 3 1 6	1 3 1 9	1 2 0 6	1 3 1 7	1 3 1 3				1 6		2·1 1·5		·021	
523	1 3 0 3	0 3 0 3	2 1 2 1	−0 4 1 1	2 3 3 1	1 3 1 3	−0 1 −0 3	−0 1 1 4	0 5 2 0	2·7 3·5		1·0 1·6	0·7	·022	·002
524	1 3 2 1		3 1 1 6	1 7 2 7	2 7 3 3							4·1 3·7		·034	
525	2 0 0 2	1 3 0 2	0 5 0 3	1 4 0 0	0 2 −0 5	0 2 1 0	−2 3 −1 3	−0·2	0·2 0·2	1·6 1 8		0·8 0·6		·012	
526	3 3 3 0		2 1 2 0	3 5 3 7	3 2 3 3							4·8 4·4	4·4	·115	·107
527	0 3 0 4	1 6 0 2	1 4 1 3	1 4 0 3	1 3 0 3	1 1 1 4	0 6 −1 2	0 4	0 1 2 0	1 8 2 0		1·2 1·1		·009	
528			2·5 2 5	3 4 3 0	2 8 3 0							2·9 2·9	2·4	·072	·068

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
529	Boss 3307	γ Virginis s.f.	12 36·6	−00 54	3·8	F1	·561	−17·5	3·6 3·4	2·9 3·6	3·4 2·4
530	Boss 3321	10 Can. Ven.	12 40·3	39 50	6·0	F8	·374	+90·2	6·2 6·2	5·2 5·5	4·8 6·0
531	Boss 3326	33 Virginis	12 41·3	10 06	5·9	K0	·530	+55·8	4·6 4·0	4·1 3·8	....
532	H.R. 4852	.....	12 41·8	81 10	6·3	A3	.....	.....	0·7 1·4	2·8 4·9	3·0 2·9
533	.....	Lal. 23900	12 43·9	25 24	6·4	G6	·367	− 0·4	6·7 4·8	5·3 5·3	....
534	Boss 3346	37 Virginis	12 46·5	03 36	6·1	K3	·033	+ 7·0	....	....	....
535	H.R. 4909	.....	12 50·4	47 45	6·0	M8	.....	.....	−1·6 −1·4	....	....
536	Boss 3367	δ Virginis	12 50·6	03 56	3·7	M4	·475	−12·7	0·6 0·2	....	....
537	Boss 3374	36 Comae Ber.	12 54·0	17 57	5·0	M0	·033	+ 5·6	....	....	....
538	C 1664	.....	12 55·7	18 55	6·1	F6	·245	+6·3	3·7 3·4	4·1 3·6	2·9 3·5
539	Boss 3380	9 Draconis	12 56·2	67 08	5·5	K0	·147	−18·9	1·6 1·3	0·5 −1·8	....
540	Boss 3383	ε Virginis	12 57·2	11 30	3·0	G6	·270	− 7·3	1·0 1·6	0·5 0·8	....
541	Boss 3397	39 Comae Ber.	13 01·4	21 42	6·0	F3	·087	+ 6·8	3·5 3·1	4·2 3·6	3·0 4·0
542	Boss 3398	40 Comae Ber.	13 01·5	23 09	5·9	M8	·065	+ 1·9	....	....	....
543	Boss 3401	41 Comae Ber.	13 02·4	28 10	4·9	K8	·088	− 6·2	−0·2 1·8:	....	....
544	Boss 3402	.....	13 02·4	62 35	6·3	G6	·043	+25·7	2·7 2·2	2·8 2·0	....
545	H.R. 4962	.....	13 04·8	17 22	6·2	K6	.....	.....	....	....	....
546	Boss 3412	α Comae Ber.	13 05·1	18 04	5·2†	F4	·446	−11·1	4·8 3·8	2·7 3·8	4·0 4·2
547	Boss 3424	β Comae Ber.	13 07·2	28 23	4·3	G1	1·184	+15·3	2·4 3·8	5·3 5·7	3·0 3·8
548	Boss 3431	.....	13 08·9	01 59	6·8	K2	·091	+15·0	....	....	....
549	Boss 3443	59 Virginis	13 11·8	09 56	5·2	G1	·381	−19·6	3·0 3·3	4·2 3·8	3·6 3·6
550	Boss 3446	σ Virginis	13 12·6	06 00	5·0	M2	·015	−19·7	....	....	....
551	Boss 3447	20 Can. Ven.	13 13·1	41 06	4·7	F3	·123	+20·2	0·2 0·0	0·9 1·2	−1·2 −0·2
552	Boss 3470	.....	13 18·6	85 17	7·4	F9	·130	+20·0	4·0 3·4	4·5 4·2	4·1 3·5

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
529	.....	.....	2·3	4·1	3·6	.....	.....	.....	.....	.....	.....	**3·3**	2·2	·077	·068
	.....	.....	2·5	3·2	3·9	.....	.....	.....	.....	.....	.....	**3·2**			
530	5·0	.....	5·5	5·4	4·5	.....	.....	.....	.....	.....	.....	**5·2**	3·9	·068	·063
	4·0	.....	4·0	4·8	5·4	.....	.....	.....	.....	.....	.....	**5·1**			
531	2·9	3·8	2·0	2·3	1·7	1·8	.....	.....	.....	.....	.....	**2·9**	4·2	·025	·008
	2·5	3·3	1·9	1·5	.....	.....	.....	.....	.....	.....	.....	**2·8:**			
532	.....	.....	3·0	.....	2·1	.....	.....	.....	.....	.....	.....	**2·3:**			
	.....	.....	2·2	0·3	2·5	.....	.....	.....	.....	.....	.....	**2·4:**	.....	·016	
533	5·6	4·2	3·5	4·8	4·5	.....	.....	.....	.....	.....	.....	**4·9**	5·3	·044	·026
	4·3	4·4	3·6	4·3	2·8	5·2	.....	.....	.....	.....	.....	**4·3**			
534	1·8	0·0	.....	−1·3	.....	0·0	−0·4	−0·7	−1·0	0·0	.....	**−0·2**	0·6	·006	
	.....	0·1	−1·2	0·4	.....	.....	1·2	0·3	−0·2	0·0	0·2	**0·1**			
535	.....	.....	.....	−2·5	.....	−1·2	−3·8	−3·5	−1·2	−3·1	.....	**−2·4**			
	.....	−1·2	−3·4	−2·2	.....	−2·6	−3·3	−2·1	−2·6	−1·4	−3·2	**−2·3**	.....	·002	
536	.....	.....	.....	−0·4	.....	1·1	1·1	0·8	−0·5	−0·6	−1·6	**0·2**	0·3	·017	·002
	.....	.....	0·0	0·5	.....	−0·8	−1·0	−0·2	−0·7	−0·5	−1·0	**−0·4**			
537	.....	.....	.....	−0·5	.....	−3·2	−0·3	−0·3	0·5	1·0	−0·5	**−0·5**	0·9	·008	
	.....	0·0	−2·3	−0·4	.....	−2·2	−0·4	−0·4	−0·3	0·3	0·5	**−0·6**			
538	.....	.....	5·3	3·0	4·2	.....	.....	.....	.....	.....	.....	**3·9**	3·4	·034	·022
	3·4	.....	3·9	4·1	4·2	.....	.....	.....	.....	.....	.....	**3·7**			
539	.....	.....	−1·7	−2·0	−2·4	−1·4	−1·5	−1·3	−2·9	−2·7	.....	**−1·4**	.....	·004	
	.....	−2·0	−2·0	−1·2	−3·0:	−0·4	0·8	.....	−3·4	−1·8	.....	**−1·4**			
540	1·3	0·2	2·3	2·2	0·4	2·3	1·6	1·6	2·4	•1·5	.....	**1·4**	0·0	·048	·034
	1·4	−0·3	2·3	2·0	2·8	1·9	0·9	1·5	.....	.....	.....	**1·4**			
541	.....	.....	1·8	4·0	2·8	.....	.....	.....	.....	.....	.....	**3·2**	.....	·028	
	.....	.....	1·9	2·9	3·8	.....	.....	.....	.....	.....	.....	**3·2**			
542	.....	.....	.....	−2·0	.....	−1·7	−3·3	−2·5	−1·2	−1·4	−1·5	**−1·9**	0·2	·002	·043
	.....	−1·9	−4·2	−2·8	.....	−1·6	−3·9	−2·0	−2·0	−1·2	−2·2	**−2·4**			
543	−0·6	0·5	.....	0·3	.....	−1·4	0·7	0·1	−0·5	−0·5	.....	**−0·2**	0·4	·011	
	0·2	−0·5	−0·2	0·6	2·6:	2·2	−0·3	0·3	−0·3	0·6	0·9	**0·5**			
544	3·3	3·1	0·7	0·3	1·0	0·9	.....	.....	.....	.....	.....	**1·8**	2·6	·010	
	2·1	1·6	0·4	−0·8	0·6	0·4	−0·2	0·5	.....	0·8	.....	**0·9**			
545	1·8	−1·4	.....	0·0	.....	−1·8	−1·4	−1·0	−1·1	−2·5	.....	**−0·9:**	.....	·004	
	−1·8	−2·5	−1·5	.....	.....	−1·1	0·2	−0·6	−2·7	−0·8	−1·1	**−1·3**			
546	.....	.....	3·0	3·5	4·2	.....	.....	.....	.....	.....	.....	**3·7**	3·9	·050	·070
	.....	.....	2·6	3·9	3·9	.....	.....	.....	.....	.....	.....	**3·7**			
547	.....	.....	4·4	4·1	3·3	.....	.....	.....	.....	.....	.....	**3·8**	4·7	·087	·131
	2·3	.....	5·3	4·8	3·6	.....	.....	.....	.....	.....	.....	**4·2**			
548	.....	.....	.....	.....	.....	.....	−1·3	−1·0	0·2	−0·1	.....	**−0·5:**	.....	·003	
	.....	−0·3	.....	−1·2	.....	.....	−2·9	.....	0·6	1·2	−0·8	**−0·6:**			
549	5·1	.....	4·1	5·3	2·9	.....	.....	.....	.....	.....	.....	**4·0**	4·4	·058	·075
	4·4	.....	5·6	4·4	2·6	.....	.....	.....	.....	.....	.....	**4·0**			
550	.....	.....	.....	−2·9	.....	−2·8	−1·6	−1·0	−0·8	−1·6	−1·4	**−1·7**	0·3	·005	
	.....	−0·5	.....	−2·2	.....	−3·2	−2·0	−1·0	−1·0	−1·5	−0·8	**−1·5**			
551	.....	.....	0·8	1·6	1·9	.....	.....	.....	.....	.....	.....	**0·7**	.....	·017	
	.....	.....	1·7	2·0	1·2	.....	.....	.....	.....	.....	.....	**1·0**			
552	3·5	.....	3·4	3·9	2·6	.....	.....	.....	.....	.....	.....	**3·7**	.....	·016	
	4·2	.....	3·0	2·2	2·0	.....	.....	.....	.....	.....	.....	**3·2**			

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
553	H.R. 5052	.....	13 19·4	37 33	6·4	M4	.....	.....	.....	.....	.....
									.....	.....	.....
554	H.R. 5067	.....	13 22·0	46 33	5·9	K0	.....	.....	0·9	0·7	.....
									−0·4	1·8	.....
555	Boss 3487	70 Virginis	13 23·5	14 19	5·2	G4	·631	+12·1	4·4	4·3	3·8
									3·8	4·4	3·6
556	Boss 3492	71 Virginis	13 24·3	11 20	5·8	K0	·069	+ 8·1	0·7	.....	.....
									1·9	2·5	.....
557	H.R. 5083	.....	13 24·7	51 14	6·3	F2	.....	.....	0·6	1·7	0·6
									2·0	2·7	1·6
558	Boss 3497	.....	13 26·1	79 10	5·9	G5	·134	+25·3	1·4	2·0	2·3
									1·3	1·6	.....
559	Boss 3499	74 Virginis	13 26·8	−05 45	4·8	M1	.....	.....	.....	.....	.....
									.....	.....	.....
560	H.R. 5102	.....	13 28·1	24 52	6·2	G8	.....	.....	−0·1	3·0	.....
									−0·8	.....	.....
561	Boss 3511	.....	13 30·3	37 42	5·0	F2	·088	+18·5	1·9	2·5	3·4
									1·9	3·0	1·7
562	H.R. 5129	.....	13 33·2	14 48	6·4	F0*n*	.....	.....	0·4	0·9	−0·1
									1·8	2·0	1·8
563	H.R. 5137	.....	13 34·3	18 47	6·5	K6	.....	.....	...	.....	....
									.....	.....	.....
564	Boss 3527	.....	13 34·8	71 45	5·7	K0	·036	+26·0	0·8	0·9	.....
									0·0	.....	.....
565	H.R. 5148	.....	13 36·3	51 02	6·3	F8	.....	.....	4·5	4·4	4·2
									4·9	5·2	4·4
566	Boss 3533	2 Boötis	13 36·3	23 01	5·8	G9	·037	+14·2	2·2	0·2	.....
									1·6	1·7	.....
567	Boss 3536	83 Ursae Maj.	13 36·9	55 12	4·8	M0	·025	− 5·2	−2·0	.....	.....
									−0·7	.....	.....
568	C 1789	.....	13 41·6	56 24	6·4	F8	·372	+ 6·3	3·5	4·5	5·1
									4·2	4·2	4·8
569	Boss 3554	.....	13 42·0	06 51	6·3	F9	·496	−23·4	3·4	5·0	4·6
									4·0	3·6	4·4
570	Boss 3555	.....	13 42·1	26 12	6·6†	F4	·067	+21·1	3·0	2·8	2·7
									2·4	3·1	3·5
571	Boss 3557	.....	13 42·2	78 34	6·1	K0	·079	+ 4·1	−0·7	0·2	.....
									1·6	1·9	.....
572	Boss 3558	τ Boötis	13 42·5	17 57	4·5	F7	·483	− 6·1	4·7	3·6	3·9
									4·3	3·9	3·8
573	Boss 3559	.....	13 42·7	39 03	5·6	G9	·111	+ 1·4	1·7	0·4	
									0·9	1·7	.....
574	Boss 3570	.....	13 44·2	31 41	5·8	G7	·043	+22·1	1·1	2·6	.....
									1·2	.....	.....
575	Boss 3572	υ Boötis	13 44·6	16 17	4·3	K9	·104	+ 5·1	.....	.....	.....
									.....	.....	.....
576	H.R. 5204	.....	13 45·4	37 06	6·4	A4	.....	.....	1·0	2·1	1·6
									1·4	2·8	1·1

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 91	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
553	.....	.....	.....	−2·9	.....	.....	−2·0	−2·1	−1·2	−1·2	.....	−1·9 :	.....	·003	
	.....	−0·8	.....	.....	.....	.....	−1·5	−0·2	−2·8	−1·4	−0·4	−1·2 :			
554	1·7	1·5	0·3	2·6	1·7	1·3	1·3	1·8	0·2	1·0	.....	1·2	.....	·012	
	1·8	1·9	−0·2	1·1	2·0	1·8	1·9	1·7	−0·8	2·2	.....	1·2			
555	5·1	4·7	2·4	4·5	2·0	.....	.....	.....	.....	.....	.....	3·9	3·9	·052	·065
	5·1	4·9	2·5	3·4	1·4	.....	.....	.....	.....	.....	.....	3·6			
556	1·0	.....	1·0	−0·4	−0·2	−1·0	1·1	1·6	0·2	1·7	.....	0·6	.....	·010	
	1·8	1·7	−0·2	−2·1	−1·1	0·5	1·4	.....	.....	1·6	.....	0·8			
557	.....	.....	4·1	.....	0·9	.....	.....	.....	.....	.....	.....	1·6	.....	·011	
	.....	.....	0·5	0·0	2·2	.....	.....	.....	.....	.....	.....	1·5			
558	4·1	.....	2·3	3·8	1·1	.....	.....	.....	.....	.....	.....	2·4	.....	·016	
	3·4	3·4	1·6	0·8	0·6	0·5	.....	.....	.....	.....	.....	1·6			
559	.....	.....	.....	−0·4	.....	−2·0	−2·0	−1·2	−1·0	−1·1	0·0	−1·1	0·6	·006	
	.....	−1·2	−3·3 :	−1·0	.....	.....	−1·4	−1·8	−2·8	−1·1	−0·8	−1·7			
560	−0·2	.....	0·1	0·3	0·2	−0·7	0·0	0·0	−0·9	−0·3	.....	0·1	.....	·006	
	−0·2	0·3	−1·2	−1·3	0·8	−1·1	0·4	−0·4	−0·4	1·2	.....	−0·2			
561	.....	.....	2·5	.....	1·9	.....	.....	.....	.....	.....	.....	2·4	2·4	·028	
	.....	.....	0·9	2·4	1·9	.....	.....	.....	.....	.....	.....	2·0			
562	.....	.....	2·3	.....	.....	.....	.....	.....	.....	.....	.....	0·9 :	.....	·008	
	.....	.....	−0·9	0·0	.....	.....	.....	.....	.....	.....	.....	0·9 :			
563	.....	.....	.....	−1·8	.....	.....	−1·1	0·3	1·5	2·2	.....	0·2 :	.....	·005	
	−0·4	−0·5	−1·5	−1·3	.....	1·0	−0·1	0·2	0·2	0·9	0·9	−0·1			
564	−0·1	0·3	1·2	−1·2	−0·5	1·6	−0·7	−0·9	−1·5	−0·1	.....	0·0	.....	·007	
	.....	0·2	0·6	−0·8	0·5	1·0	−0·8	1·3 :	−0·7	0·3	.....	0·1			
565	6·0	.....	5·5	5·0	3·6	.....	.....	.....	.....	.....	.....	4·7	.....	·044	
	6·0	.....	4·0	3·6	2·5	.....	.....	.....	.....	.....	.....	4·4			
566	1·3	2·4	−0·3	0·7	0·4	0·8	−0·2	0·7	0·0	2·0	.....	0·8	.....	·010	
	1·8	1·7	−0·6	−0·8	0·0	1·1	0·5	0·3	−0·1	2·0	.....	0·8			
567	.....	.....	.....	−0·6	.....	−1·7	0·6	−0·1	−0·2	−1·1	−0·2	−0·7	.....	·009	
	.....	−0·6	0·2	0·7	.....	1·0	−0·4	0·0	−1·2	−1·1	−0·7	−0·3			
568	3·9	.....	5·9	4·1	4·5	.....	.....	.....	.....	.....	.....	4·5	3·5	·042	·027
	3·8	.....	5·0	4·0	5·2	.....	.....	.....	.....	.....	.....	4·5			
569	5·4	.....	5·0	2·1	5·3	.....	.....	.....	.....	.....	.....	4·4	4·3	·041	·028
	3·5	.....	5·5	4·0	5·1	.....	.....	.....	.....	.....	.....	4·3			
570	.....	.....	2·0	3·1	2·1	.....	.....	.....	.....	.....	.....	2·6	.....	·014	
	.....	.....	0·8	1·6	1·8	.....	.....	.....	.....	.....	.....	2·2			
571	0·2	2·5	1·0	0·7	0·0	1·0	1·4	2·1	0·7	1·5	.....	0·9	.....	·010	
	1·2	0·8	0·1	0·4	1·1	1·5	1·7	1·5	0·6	1·6	.....	1·2			
572	5·0	.....	5·0	4·9	3·2	.....	.....	.....	.....	.....	.....	4·3	3·0	·090	·046
	.....	.....	4·7	4·5	3·9	.....	.....	.....	.....	.....	.....	4·2			
573	0·3	1·2	1·1	1·7	0·6	1·8	1·0	1·0	−0·7	1·4	.....	1·0	.....	·012	
	1·9	0·5	1·1	1·5	1·1	1·5	0·3	.....	.....	1·7	.....	1·2			
574	1·3	1·3	0·6	−0·4	−0·4	0·7	0·0	0·7	−1·1	1·3	.....	0·6	.....	·010	
	0·9	1·1	0·8	−1·0	0·8	1·4	2·0	.....	0·4	1·0	.....	0·9			
575	2·8	2·0	.....	+0·3	.....	0·0	−0·7	0·3	−0·9	0·0	.....	0·4	.....	·015	
	1·4	0·8	−0·2	0·0	.....	.....	−0·3	−1·3	−2·0	0·6	−0·1	−0·1			
576	.....	.....	0·8	.....	.....	.....	.....	.....	.....	.....	.....	1·4	.....	·011	
	.....	.....	2·2	.....	.....	.....	.....	.....	.....	.....	.....	1·9			

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
577	Boss 3581	.....	13 46·7	35 10	6·0	M1	·070	−29·8	.....	.....	.....
									.....	.....	.....
578	Boss 3584	Can. Ven.	13 47·4	34 57	5·0	M3	·040	−30·1	−1·0	.....	.....
									.....	.....	.....
579	Boss 3588	7 Boötis	13 48·4	18 25	5·7	G6	·036	+ 0·8	0·0	2·6	.....
									.....	1·8	.....
580	Boss 3589	10 Draconis	13 48·5	65 13	4·8	M4	·005	+ 2·1	.....	.....	.....
									.....	.....	.....
581	Boss 3591	.....	13 48·7	29 08	5·8	A6	·115	− 1·2	1·1	2·9	4·3
									1·6	4·2	2·6
582	Boss 3596	η Boötis	13 49·9	18 54	2·8	G1	·373	+10·5	3·4	1·5	3·9
									3·3	1·6	4·3
583	Boss 3598	.....	13 50·4	79 29	6·6	G8	·044	+ 7·4	.....	2·7	.....
									.....	2·4	.....
584	H.R. 5243	.....	13 51·1	14 34	6·2	F6	.....	.....	2·8	5·4	5·0
									3·7	4·2	5·1
585	H.R. 5245	.....	13 51·8	32 31	6·3	F2	.....	.....	1·6	0·9	3·9
									2·6	0·8	1·6
586	Boss 3601	9 Boötis	13 52·0	27 59	5·2	K5	·065	−27·7	0·4	.....	.....
									.....	.....	.....
587	Boss 3631	.....	14 04·6	49 56	5·4	M2	·068	− 0·2	.....	.....	.....
									.....	.....	.....
588	Boss 3635	*d* Boötis	14 05·8	25 34	5·6†	F6	.....	.....	4·1	2·1	4·1
									4·6	1·4	4·6
589	H.R. 5307	.....	14 06·5	01 50	6·3	F6	.....	.....	5·0	3·5	5·2
									5·0	3·0	4·6
590	Boss 3649	4 Ursae Min.	14 09·2	78 01	5·0	K4	·038	+21·7	0·5	1·8	.....
									0·7	.....	.....
591	Boss 3650	14 Boötis	14 09·3	13 26	5·5	F7	·264	−27·3	4·5	3·3	3·4
									3·6	2·7	3·5
592	Boss 3652	.....	14 09·9	52 16	6·6	A7	·067	− 9·7	2·6	3·0	4·2
									3·0	4·2	2·8
593	Boss 3658	.....	14 10·3	42 00	6·2	K3	·120	+10·1	1·3	3·2	.....
									1·4	3·3	.....
594	Boss 3662	α Boötis	14 11·1	19 42	0·2	K0	2·283	+ 7·1	1·5	−0·4	.....
									2·8	1·2	.....
595	H.R. 5346	.....	14 11·9	20 35	6·4	F8	.....	.....	3·2	4·7	3·5
									2·1	4·9	2·7
596	H.R. 5347	.....	14 12·3	40 13	6·3	F4	.....	.....	4·1	2·3	2·6
									3·8	3·4	1·2
597	H.R. 5352	.....	14 12·7	15 44	6·0	M2	.....	.....	.....	.....	.....
									.....	.....	.....
598	Boss 3673	A Boötis	14 13·8	35 58	4·8	K0	·013	−12·1	0·2	0·7	.....
									0·1	2·4	.....
599	Boss 3681	20 Boötis	14 15·1	16 46	5·0	K6	·151	+ 5·0	2·4	2·0	.....
									2·4	.....	.....
600	H.R. 5374	.....	14 15·8	30 53	6·3	A3	.....	.....	0·0	1·1	2·7
									2·6	3·9	2·5

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
577	.....	.....	.....	0·9	.....	--1·2	−0·8	−0·5	0·9	0·0	−0·5	**−0·2**			
	.....	−0·8	−1·4	0·4	.....	−1·0	−0·2	−0·1	−1·0	−0·9	0·1	**−0·5**	0·7	**·005**	·012
578	.....	.....	.....	−0·2	.....	−0·8	−0·2	−0·7	−1·2	−1·9	−1·9	**−0·9**			
	.....	0·0	−2·1	−0·3	.....	−1·3	−2·2	−0·6	−0·9	−1·4	−1·1	**−1·1**	0·4	**·006**	
579	0·4	2·2	1·0	0·3	−1·0	−1·0	−0·3	−0·1	−0·5	1·3	.....	**0·4**			
	0·9	1·1	0·9	−0·2	.....	−1·3	0·9	.....	1·5	0·7	.....	**0·7**	.....	**·009**	
580	.....	.....	.....	−0·4	.....	−1·8	−2·0	−1 1	−0·7	−0·0	−1·4	**−1·0**			
	.....	−0·3	−2·2	−0·7	.....	−2·0	−2·9	−1·2	−1·4	−1·1	−1·5	**−1·5**	−0·5	**·006**	
581	.....	.....	2·7	2·0	2·1	.....	.....	.....	.....	.....	.....	**2·5**			
	.....	.....	2·2	1·3	1·9	.....	.....	.....	.....	.....	.....	**2·3**	.....	**·021**	
582	5·3	.....	2·8	3·6	2·9	.....	.....	.....	.....	.....	.....	**3·3**			
	3·8	3·5	4·4	3·5	4·0	.....	.....	.....	.....	.....	.....	**3·6**	2·8	**·135**	
583	2·9	1·0	0·9	0·8	0·0	0·7	−1·2	−0·8	−0·3	1·2	.....	**0·7**			
	0·6	0·3	−1·4:	−1·8:	.....	.....	−1·3	.....	−0·2	1·2	.....	**0·3**	.....	**·006**	
584	3·3	.....	3·6	4·0	2·9	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	2·6	2·2	.....	.....	.....	.....	.....	.....	.....	**3·6**	.....	**·032**	
585	.....	.....	3·0	4·0	2·3	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	0·9	2·4	1·7	.....	.....	.....	.....	.....	.....	**1·7**	.....	**·015**	
586	0·8	0·3	.....	−0·9	.....	−0·4	0·5	0·1	−1·5	−1·3	.....	**−0·3**			
	−0·6	−2·2	−1·7	0·0	−0·9	−0·4	−0·3	0·4	−0·7	−0·8	−0·8	**−0·7**	.....	**·007**	
587	.....	.....	.....	−0·8	.....	−3·3	−0·2	+0·4	−1·0	−1·1	−1·0	**−1·0**			
	.....	−0·3	−0·9	−0·1	.....	−1·3	−1·2	−0·7	−1·3	−1·2	−1·5	**−0·9**	−0·2	**·005**	
588	.....	.....	3·3	4·0	2·0	.....	.....	.....	.....	.....	.....	**3·3**			
	3·0	.....	2·2	3·0	3·0	.....	.....	.....	.....	.....	.....	**3·1**	1·9	**·033**	
589	.....	5·5	4·7	2·3	.....	.....	.....	.....	.....	.....	.....	**4·4**			
	.....	.....	3·4	3·6	.....	.....	.....	.....	.....	.....	.....	**3·9**	.....	**·037**	
590	−0·2	2·0	−0·2	.....	−0·7	0·3	−1·0	+0·5	−0·1	−0·6	.....	**0·2**			
	1·9	0·9	−0·1	−0·7	−0·7	1·4	1·2	0·7	−1·5	−0·9	−0·7	**0·2**	0·7	**·011**	
591	3·3	.....	3·1	4·0	3·8	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	3·4	4·2	4·0	.....	.....	.....	.....	.....	.....	**3·6**	4·1	**·043**	·097
592	.....	.....	5·5	3·7	3·1	.....	.....	.....	.....	.....	.....	**3·7:**			
	.....	.....	2·8	2·2	3·4:	.....	.....	.....	.....	.....	.....	**3·0**	.....	**·022**	
593	2·4	0·0	2·5	1·0	2·8	3·0	1·7	2·9	3·0	3·0	.....	**2·2**			
	2·6	1·4	2·5	2·9	2·8	1·9	2·4	2·6	3·6	3·8	3·6	**2·6**	0·7	**·017**	·025
594	−0·8	−0·4	2·4	2·6	−0·6	0·9	−1·0	−0·7	−1·3	−2·2	.....	**0·0**			
	.....	0·1	1·5	1·3	−1·1	0·8	0·2	0·3	−1·5	−1·6	.....	**0·4**	1·2	**·100**	·075
595	6·3	.....	2·9	4·5	2·9	.....	.....	.....	.....	.....	.....	**4·0**			
	6·2	.....	3·4	3·2	.....	.....	.....	.....	.....	.....	.....	**3·8**	.....	**·032**	
596	.....	.....	3·2	3·6	3·3	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	4·5	3·9	4·2	.....	.....	.....	.....	.....	.....	**3·5**	.....	**·026**	
597	.....	.....	.....	−0·2	.....	.....	−0·2	−1·2	−1·3	−2·1	.....	**−1·0**			
	.....	−0·3	.....	−0·9	.....	.....	−2·2	−1·0	−2·4	−0·7	−1·3	**−1·3**	.....	**·004**	
598	1·0	1·8	1·4	0·3	0·0	2·0	2·5	0·7	0·0	0·7	.....	**0·9**			
	1·5	1·9	−0·6	−1·2	0·0	1·4	1·4	.....	.....	0·3	.....	**0·7**	2·1	**·016**	
599	0·8	0·5	.....	1·8	.....	2·6	2·6	2·4	0·8	1·9	.....	**1·8**			
	3·3	0·8	−1·3	0·3	2·3	2·5	1·3	0·6	1·0	1·4	1·7	**1·3**	.....	**·020**	
600	.....	.....	2·3	.....	1·5	.....	.....	.....	.....	.....	.....	**1·5:**			
	.....	.....	2·8	1·5	2·1	.....	.....	.....	.....	.....	.....	**2·6:**	.....	**·014**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
601	.....	Lal. 26289	14 18·1	01 43	6·3	G2	·525	− 7·6	5·1 4·3	6·1 6·8	3·4 4·6
602	H.R. 5387	.....	14 18·6	25 48	6·2	F5	.....	.....	2·5 3·7	2·9 4·5	2·2 3·6
603	H.R. 5394	.....	14 19·4	08 33	6·2	K4	.....	.....	....	....	....
604	Boss 3704	θ Boötis	14 21·8	52 19	4·1	F6	·467	+ 3·6	3·0 3·1	2·8 2·8	3·7 3·3
605	Boss 3715	24 Boötis	14 25·2	50 18	5·6	G3	·307	+ 6·3	2·6 2·6	0·2 2·1	3·2 0·9
606	Boss 3717	σ Boötis	14 27·5	30 49	3·8	K3	·148	+ 0·5	..... 1·6	2·0 1·6:	....
607	H.R. 5436	.....	14 28·4	63 38	6·0	F4	.....	.....	3·3 2·8	2·8 4·6	4·8 4·2
608	H.R. 5445	.....	14 29·9	32 59	6·3	F6	.....	.....	3·1 4·5	2·7 4·0	3·8 4·6
609	H.R. 5448	.....	14 30·5	37 04	6·2	K5	.....	.....	....	....	....
610	Boss 3736	.....	14 33·6	18 44	6·0	K1	·093	− 2·4	0·9 0·6	1·9 2·2	....
611	Boss 3740	.....	14 34·5	44 04	5·9	K2	·109	−34·0	0·3	..... −1·5	....
612	Boss 3741	.....	14 34·7	52 00	6·8	F4	·050	− 9·5	4·6 3·2	2·9 3·6	2·6 2·1
613	H.R. 5472	.....	14 35·8	22 24	6·2	F1	.....	.....	2·0 1·8	1·6 2·2	3·8 2·2
614	H.R. 5479	.....	14 36·4	80 06	6·4	K6:	.....	.....	....	....	....
615	Boss 3753	31 Boötis	14 36·8	08 35	5·0	G5	·007	−10·0	1·1 0·2	0·2 1·2	....
616	Boss 3754	32 Boötis	14 36·9	12 05	5·6	G6	·201	−10·4	0·6 −1·0:	2·2 2·3	....
617	Boss 3758	μ Virginis	14 37·8	−05 13	4·0	F3	·338	+16·3	3·0 2·0	3·0 2·4	2·2 1·6
618	Boss 3761	34 Boötis	14 39·0	26 57	4·9	M0	·020	+22·0	....	....	....
619	Boss 3764	.....	14 39·8	40 51	5·8	K2	·025	+25·6	−0·5 1·2	2·1 1·9	....
620	Boss 3771	ε Boötis br.	14 40·6	27 30	2·7	G5	·045	− 1·9	1·0 1·4	....	....
621	H.R. 5524	.....	14 44·0	24 47	6·0	F6	.....	.....	2·8 3·9	2·7 2·9	3·9 3·7
622*	.....	RY Boötis	14 45·2	23 27	7·2	F4	·051	+15·4	1·7 2·7	4·4 3·1	2·7 3·4
623	Boss 3785	.....	14 45·2	38 13	6·0	F3	·274	−23·0	3·1 3·3	2·9 3·7	3·2 2·4
624	Boss 3793	preceding	14 46·3	49 07	5·6	F4	·113	−17·2	3·7 3·3	1·9 2·1	3·9 3·8

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
601	5·9	.....	4·3	4·2	6·0	.....	.....	.....	.....	.....	.....	**5·0**			
	5·2	5·6	4·2	2·9	4·1	.....	.....	.....	.....	.....	.....	**4·7**	5·7	·052	·070
602	.....	.....	3·4	4·3	3·0	.....	.....	.....	.....	.....	.....	**3·1**			
	.....	.....	4·6	2·4	3·8	.....	.....	.....	.....	.....	.....	**3·8**	.....	·028	
603	3·7	1·2	.....	0·0	.....	−0·6	−0·7	2·3	2·0	2·8	.....	**1·3**			
	2·4	0·0	.....	−0·8:	.....	.....	2·2	2·0	2·3	2·3	2·3	**1·6**	.....	·052	
604	.....	.....	4·9	5·3	3·1	.....	.....	.....	.....	.....	.....	**3·8**			
	2·8	.....	3·5	4·2	3·1	.....	.....	.....	.....	.....	.....	**3·3**	3·0	·077	·067
605	2·1	.....	−2·7	−1·8	0·7	.....	.....	.....	.....	.....	.....	**0·6:**			
	.....	.....	−0·8	−1·3	1·9	.....	.....	.....	.....	.....	.....	**0·9**	1·8	·011	·023
606	−0·2	0·0	1·5	−0·4	0·0	+0·1	−1·4	−0·4	−0·3	−0·6	.....	**0·0**			
	−0·1	1·4	2·2	0·0	−0·2	−0·4	0·2	0·9	0·2	−0·2	0·4	**0·6**	0·8	·020	·036
607	.....	.....	5·1	.....	2·1	.....	.....	.....	.....	.....	.....	**3·6**			
	.....	.....	3·2	3·4	3·8	.....	.....	.....	.....	.....	.....	**3·7**	.....	·034	
608	.....	.....	3·2	4·8	3·2	.....	.....	.....	.....	.....	.....	**3·5**			
	.....	.....	2·8	2·8	3·8	.....	.....	.....	.....	.....	.....	**3·8**	.....	·030	
609	.....	.....	.....	−2·7	.....	−1·4	−0·7	+0·7	−0·9	−0·9	.....	**−1·0:**			
	1·3	−1·0	−1·2	−0·7	.....	.....	−1·3	−0·3	−1·6	−0·4	−0·8	**−0·7**	.....	·004	
610	0·7	2·0	0·2	0·1	0·4	1·1	0·0	−0·1	1·6	1·8	.....	**0·9**			
	0·3	−0·1	−0·6	−0·9	0·0	1·0	−0·8	1·4	0·9	0·1	−0·8	**0·2**	1·9	·008	·057
611	0·2	−0·9	.....	−1·4	.....	−2·5	−3·5	−0·7	−2·2	−3·1	.....	**−1·5**			
	−3·7	−2·5	−2·5	−2·1	.....	−0·8	−2·3	−3·4	−1·8	−1·9	−2·1	**−2·2**	.....	·003	
612	.....	.....	3·5	4·3	2·7	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	2·2	2·8	3·3	.....	.....	.....	.....	.....	.....	**2·9**	.....	·019	
613	.....	.....	4·2	0·5	2·3	.....	.....	.....	.....	.....	.....	**2·4**			
	.....	.....	2·4	0·6	2·1	.....	.....	.....	.....	.....	.....	**1·9**	.....	·016	
614	.....	.....	.....	.....	.....	.....	−0·7	−0·7	0·3	0·4	.....	**−0·2:**			
	0·0	−0·6	.....	.....	.....	.....	−0·1	0·1	0·6	0·6	1·3	**0·3:**	.....	·005	
615	0·6	3·0	1·3	−0·7	0·9	0·5	.....	.....	.....	.....	.....	**0·9**			
	2·1	1·1	1·2	−0·2	0·2	1·5	.....	.....	.....	1·2	.....	**0·9**	.....	·015	
616	0·0	0·7	0·1	0·0	0·1	0·2	−0·3	−0·2	0·0	1·1	.....	**0·4**			
	1·6	0·9	−0·6	−1·5	0·3	0·0	.....	.....	.....	0·4	.....	**0·3**	1·0	·009	
617	.....	.....	1·0	0·8	3·0	.....	.....	.....	.....	.....	.....	**2·2**			
	.....	.....	0·2	1·3	3·0	.....	.....	.....	.....	.....	.....	**1·8**	2·4	·040	·048
618	.....	.....	.....	.....	.....	.....	−1·5	−1·9	−2·1	−1·8	.....	**−1·8:**			
	−0·2	0·0	.....	.....	.....	.....	−2·0	−1·2	−2·1	−2·0	−2·0	**−1·4:**	.....	·005	
619	0·2	0·0	2·1	0·2	−0·7	−0·5	−0·7	−1·6	−1·9	−1·9	.....	**−0·3**			
	0·6	0·8	−1·2	0·4	−2·7	0·1	−0·3	0·1	−0·3	−1·3	−0·6	**−0·1**	.....	·006	
620	0·4	−0·5	3·0	0·4	.....	1·1	−0·4	−0·7	0·0	1·0	.....	**0·5**			
	1·2	0·3	2·6	−0·1	.....	1·5	0·3	1·1	.....	.....	.....	**1·0**	−0·9	·041	·015
621	5·1	.....	4·1	2·8	1·5	.....	.....	.....	.....	.....	.....	**3·3**			
	5·1	.....	1·4	1·8	2·0	.....	.....	.....	.....	.....	.....	**3·0**	.....	·027	
622	.....	.....	2·0	3·6	2·4	.....	.....	.....	.....	.....	.....	**2·8**			
	.....	.....	2·8	3·4	3·7	.....	.....	.....	.....	.....	.....	**3·2**	0·5:	·014	
623	.....	.....	3·6	3·4	3·6	.....	.....	.....	.....	.....	.....	**3·3**			
	.....	.....	2·9	3·6	3·8	.....	.....	.....	.....	.....	.....	**3·3**	2·4	·029	·015
624	.....	.....	3·4	0·4	2·9	.....	.....	.....	.....	.....	.....	**2·7**			
	.....	.....	3·6	2·8	4·1	.....	.....	.....	.....	.....	.....	**3·3**	.....	·030	

80600—7½

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
625	Boss 3793	following	14 46·3	49 07	6·4†	F5	·113	−13·1	3·8 4·0	2·7 3·8	4·2 3·5
626	H.R. 5537	.....	14 46·3	51 48	6·4	F3	.....	.....	1·2 2·6	2·6 3·2	4·2 5·2
627	Boss 3795	.....	14 46·6	37 40	5·5	G9	·228	−51·8	3·1 2·0	2·6 2·1	....
628	Boss 3798	ξ Boötis br.	14 46·8	19 31	4·8†	G7	·170	+18·5	4·6 4·2	6·0 5·7	....
629	Boss 3803	.....	14 48·9	59 42	5·7	K4	·179	+24·8	0·9 1·1	1·2	....
630	.....	Lal. 27137	14 48·9	19 34	6·0	K0	·485	−27·7	3·0 3·8	5·2 5·9	....
631	Boss 3809	β Ursae Min.	14 51·0	74 34	2·2	K4	·028	+29·8	0·1 0·8	2·0 1·2	....
632	Boss 3816	.....	14 52·4	00 14	5·7	K2	·070	+33·1	....	0·8 2·3	....
633	Boss 3817	.....	14 52·5	16 48	5·8	G6	·033	− 1·8	0·8 0·5	0·7 1·5	....
634	H.R. 5584	.....	14 54·5	04 58	6·2	M1	.....	.....	....	... .	....
635	Boss 3827	.....	14 56·0	66 20	4·9	M7	·080	+21·5	−1·3 −0·9	....	....
636	Boss 3831	2 Serpentis	14 56·7	00 14	5·9	K2	·030	−21·5	....	....	....
637	Boss 3833	.....	14 57·1	82 55	5·7	G0	·294	−34·9	5·4 5·0	4·1 3·1	4·2 3·0
638	Boss 3836	β Boötis	14 58·2	40 47	3·6	G4	·059	− 3·9	0·5 0·4	−0·2 1·2	0·8 1·0
639	H.R. 5612	.....	14 59·6	45 02	6·4	F5	.....	.....	2·5 3·7	2·4 3·1	3·6 3·3
640	Boss 3843	9 Ursae Min.	15 00·4	72 09	6·7	F9	·398	−33·7	5·6 5·1	4·2 4·2	5·4 5·5
641	Boss 3847	44 Boötis br.	15 00·5	48 03	5·3	G1	·385	−10·1	4·9 5·3	4·7 6·5	..... 6·4
642	H.R. 5631	.....	15 02·7	05 52	6·2	G6:	.....	.....	1·3 −0·3:	.... 2·4	....
643	Boss 3854	.....	15 02·7	36 50	6·3	F8	·063	+ 9·4	3·4 3·4	4·2 4·4	3·1 3·2
644	Boss 3855	45 Boötis	15 02·9	25 16	5·0	F5	·263	+ 8·4	5·7 4·0	3·5 4·3	3·5 3·4
645	Boss 3856	.....	15 03·4	54 56	5·2	G5	·047	+29·9	2·6 1·8	0·5 1·2	....
646	Boss 3859	46 Boötis	15 04·1	26 41	5·7	K1	·028	+33·9	−0·8 0·4	... 2·3	....
647	Boss 3860	.....	15 04·2	25 29	5·9	K2	·015	− 0·7	..... −0·4	..... −2·2	....
648	H.R. 5659	.....	15 08·3	19 40	6·4	G6	.....	.....	2·1 4·8	6·0 5·8	....

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
625	.....	.....	3·7	4·1	3·0	.....	.....	.....	.....	.....	.....	3·6	.....	·027	
	.....	.....	3·2	3·0	3·7	.....	.....	.....	.....	.....	.....	3·5			
626	.....	.....	4·0	4·2	2·1	.....	.....	.....	.....	.....	.....	3·0	.....	·021	
	.....	.....	3·0	2·4	1·8	.....	.....	.....	.....	.....	.....	3·0			
627	2·1	1·7	0·3	−0·2	2·5	0·6	0·5	0·8	−1·0	1·3	.....	1·2	.....	·015	
	1·0	2·6	1·1	1·2	1·6	1·8	1·7	.....	.....	1·1	.....	1·6			
628	5·6	6·0	3·4	5·9	5·6	.....	.....	.....	.....	.....	.....	5·3	5·8	·126	·178
	5·8	4·4	4·0	4·8	.....	6·0	5·7	7·2	.....	.....	.....	5·3			
629	0·5	1·9	2·5	0·8	.....	0·2	0·9	1·1	−0·9	0·2	.....	0·8	.....	·010	
	2·2	1·2	−1·9	0·4	−1·5	1·4	2·2	1·9	0·2	0·9	0·4	0·7			
630	6·7	5·4	4·9	3·0	4·2	.....	.....	.....	5·8	5·6	.....	4·9	5·9	·070	·086
	6·4	5·9	6·4	4·7	6·5	6·3	5·2	6·0	5·4	4·9	4·9	5·6			
631	1·8	−1·7	.....	0·3	.....	−0·3	−1·5	−0·5	−1·0	−1·4	.....	−0·2	0·5	·033	·014
	0·2	−0·6	0·4	0·2	−0·5	0·0	−1·4	−0·2	−0·2	−1·6	−1·1	−0·2			
632	1·8	1·1	1·5	−1·5	3·8	0·5	0·3	0·0	0·4	0·7	.....	0·8	1·8	·011	·044
	1·2	2·0	0·0	−0·2	.....	.....	1·8	1·6	0·6	0·6	0·0	0·9			
633	1·7	2·3	−0·1	1·3	0·6	0·7	.....	.....	.....	.....	.....	1·0	.....	·010	
	0·6	0·8	−0·2	−0·6	1·2	0·6	1·3	1·5:	2·4:	0·0	.....	0·7			
634	.....	.....	.....	.....	.....	.....	−1·4	−1·5	0·4	−1·0	.....	−0·9:	.....	·004	
	.....	.....	.....	.....	.....	.....	−2·5	−1·2	−0·8	−0·2	−0·6	−1·1:			
635	.....	.....	.....	−2·2	.....	−1·6	−3·7	−2·6	−1·1	−1·2	−2·0	−2·0	−0·6	·004	
	.....	−1·2	−1·2	−1·2	.....	−2·0	−2·5	−2·1	−2·8	−1·7	−2·6	−1·8			
636	.....	.....	.....	.....	.....	.....	−3·4	−2·4	−2·4	−3·7	.....	−3·0:	.....	·002	
	−5·0	−2·0	.....	.....	.....	.....	−3·9	−1·4	−3·0	−2·3	−3·0	−2·9			
637	3·2	.....	2·7	4·0	4·0	.....	.....	.....	.....	.....	.....	4·0	3·6	·041	·010
	3·7	.....	3·4	3·6	2·4	.....	.....	.....	.....	.....	.....	3·5			
638	1·3	1·0	0·1	0·3	0·5	.....	.....	.....	.....	.....	.....	0·5	−0·7	·027	·030
	1·6	1·9	1·2	0·8	1·5	−0·6	1·3	1·0	.....	0·4	.....	1·0			
639	.....	.....	4·3	2·4	2·5	.....	.....	.....	.....	.....	.....	3·0	.....	·022	
	.....	.....	3·7	2·4	3·7	.....	.....	.....	.....	.....	.....	3·3			
640	5·8	.....	4·0	1·3	4·9	.....	.....	.....	.....	.....	.....	4·5	4·3	·034	·043
	4·6	.....	3·0	2·6	4·9	.....	.....	.....	.....	.....	.....	4·3			
641	5·1	.....	4·8	6·7	4·4	.....	.....	.....	.....	.....	.....	5·1	4·6	·096	
	5·2	.....	5·3	4·8	3·4	.....	.....	.....	.....	.....	.....	5·3			
642	−0·6	1·0	0·7	2·5	0·9	0·3	−1·7	−0·2	−0·9	0·8	.....	0·4:	.....	·008	
	0·6	0·6	0·6	1·2	.....	0·6	.....	.....	.....	1·0	.....	0·8:			
643	4·6	.....	2·9	3·5	3·3	.....	.....	.....	.....	.....	.....	3·6	.....	·027	
	3·6	3·4	2·4	2·5	.....	.....	.....	.....	.....	.....	.....	3·3			
644	.....	.....	2·2	4·1	4·0	.....	.....	.....	.....	.....	.....	3·8	3·3	·057	·059
	.....	.....	3·2	3·4	4·0	.....	.....	.....	.....	.....	.....	3·7			
645	1·3	.....	1·0	−1·7	1·2	0·6	.....	.....	.....	.....	.....	0·8	.....	·013	
	2·2	1·8	−0·6	−1·7	0·4	0·7	.....	.....	.....	.....	.....	0·7			
646	0·0	0·5	0·2	−0·1	.....	2·2	0·2	−1·3	−0·9	−1·8	.....	−0·2	.....	·007	
	0·9	1·5	0·6	−1·1	0·1	1·9	.....	.....	−1·2	−1·0	.....	0·3			
647	0·8	0·0	.....	−2·4	.....	.....	−2·6	−1·2	−1·4	−1·3	.....	−1·2:	.....	·004	
	.....	−2·1	−1·7	−2·1	.....	.....	−0·3	.....	−1·4	0·3	.....	−1·2:			
648	6·5	6·2	3·9	6·5	3·8	.....	.....	.....	.....	.....	.....	5·0	.....	·048	
	7·8:	.....	3·4	2·9	5·4	2·6	3·8	.....	.....	.....	.....	4·6			

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
649	Boss 3887	δ Boötis	15 11·5	33 41	3·5	G5	·155	+ 3·7	1·6 3·2	1·3 −0·2	....
650	Boss 3895	5 Serpentis	15 14·2	02 09	5·2	F7	·644	+67·1	3·5 4·0	4·0 4·0	4·5 5·0
651	H.R. 5702	.....	15 15·4	32 54	6·1	A2	.....	.....	0·4 1·0	1·4 2·3	2·4 2·3
652	Boss 3907	6 Serpentis	15 16·0	01 04	5·5	K2	·122	+23·5	..... −0·4	3·0 3·4	....
653	Boss 3908	.....	15 16·0	29 59	5·6	G9	·134	−36·9	0·8 0·9	2·9 1·5	....
654	H.R. 5716	.....	15 17·3	44 48	5·9	F3	.....	.....	1·2 1·8	1·2 0·9	3·8 3·8
655	Boss 3923	η Cor. Bor.	15 19·1	30 39	5·6†	G0	·237	+ 6·8	5·9 5·1	4·8 5·0	6·3 5·5
656	Boss 3926	μ^1 Boötis	15 20·7	37 44	4·5	A9*n*	·166	+ 5·1	1·5 2·4	1·4 4·2	2·8 2·4
657	Boss 3927	μ^2 Boötis	15 20·7	37 41	7·2†	G0	·170	+ 7·7	6·4 4·3	6·0 3·6	3·2 5·0
658	Boss 3930	.....	15 21·0	63 42	5·8	K3	·113	−30·8	0·7 0·8	2·0 1·7	....
659	Boss 3933	.....	15 22·4	34 41	5·9	K4	·118	−31·2	1·5 0·4	1·2	....
660	Boss 3936	ι Draconis	15 22·7	59 19	3·5	K1	·011	+ 5·2	1·5 2·1	1·9 1·8	....
661*	Boss 3940	β Cor. Bor.	15 23·7	29 27	4·2†	F0	·186	− 4·7	0·4 0·7	−0·2 0·5	−2·2 −2·4
662	H.R. 5752	.....	15 25·6	47 35	6·0	A3	.....	.....	−0·3 −0·6	0·3 1·6	4·6 3·1
663	.....	Lal. 28358	15 26·6	57 47	6·9	F5	·299	−16·3	5·9 5·1	2·5 2·8	4·6 4·0
664	Boss 3960	δ Serpentis ft.	15 30·0	10 53	5·2	A9	·057	−32·3	1·9 2·1	1·7 1·9	0·7 −0·1
665	Boss 3960	δ Serpentis br.	15 30·0	10 53	4·2	A9	·066	−28·7	1·9 1·8	2·7 3·3	0·3 0·2
666	H.R. 5811	.....	15 32·6	54 16	6·0	K4	.....	.....	−0·2 2·1	2·0	....
667	H.R. 5817	.....	15 33·3	52 24	6·5	A8	.....	.....	3·7 3·6	2·1 2·0	4·3 2·2
668	Boss 3979	φ Boötis	15 34·2	40 41	5·4	G6	·082	+ 6·7	3·6 4·2	1·4 2·1	....
669	Boss 3982	.....	15 34·4	77 41	5·3	K8	·041	−11·2	0·8 2·1	....	....
670	Boss 3992	19 Serpentis	15 36·4	16 21	6·0	G4	·036	+19·4	3·2 2·5	1·9 1·3	1·2 1·2
671	Boss 4001	α Serpentis	15 39·3	06 44	2·8	K3	·142	+18·6	3·2 2·2	0·0 2·0	....
672	Boss 4003	π Cor. Bor.	15 40·1	32 50	5·6	K0	·040	+13·5	0·9 1·8	2·5 2·4	....

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
649	0·9	1·5	1·0	1·6	0·6	0·1	1·8	0·6	0·2	0·5	.....	1·0			
	2·0	3·7	0·6	1·1	0·8	0·2	2·0	2·0	.....	0·2	.....	1·3	−0·6	·034	·031
650	5·1	.....	4·2	3·3	3·0	.....	.....	.....	.....	.....	.....	3·9			
	3·4	.....	4·1	4·1	4·2	.....	.....	.....	.....	.....	.....	4·1	3·5	·058	·055
651	.....	.....	6·0	.....	0·4	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	3·0	0·9	0·4	.....	.....	.....	.....	.....	.....	1·6	.....	·014	
652	2·8	1·6	1·5	0·6	.....	.....	0·6	0·7	0·2	0·8	.....	1·3			
	2·0	1·4	0·0	0·3	.....	−0·2	0·0	0·5	1·8	1·9	0·8	1·0	1·8	·013	
653	1·2	3·0	−0·3	−0·9	−0·5	−0·4	−0·1	0·0	−1·1	0·3	.....	0·4			
	0·7	1·2	−0·9	0·0	0·4	0·7	1·0	.....	−0·4	1·3	.....	0·6	.....	·010	
654	.....	.....	1·8	.....	2·6	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	0·5	2·6	3·6	.....	.....	.....	.....	.....	.....	2·2	.....	·018	
655	5·5	.....	3·9	6·0	4·3	.....	.....	.....	.....	.....	.....	5·2			
	4·9	.....	4·8	5·0	2·9	.....	.....	.....	.....	.....	.....	4·8	4·3	·076	·084
656	.....	.....	1·0	.....	2·5	.....	.....	.....	.....	.....	.....	1·8			
	.....	.....	2·0	1·3	2·8	.....	.....	.....	.....	.....	.....	2·5	2·2	·034	·046
657	5·9	.....	7·0	6·0	6·0	.....	.....	.....	.....	.....	.....	5·8			
	6·4	5·3	5·2	3·6	5·4	.....	.....	.....	.....	.....	.....	4·8	4·7	·042	·046
658	0·7	.....	3·7	−0·4	0·4	−1·0	0·2	0·7	0·0	0·7	.....	0·7			
	1·6	0·6	−1·2	−0·8	−0·6	1·2	1·0	2·0	0·0	−0·2	−0·3	0·4	.....	·009	
659	1·2	2·9	−0·2	0·4	−0·7	−0·5	0·8	−0·8	−1·0	−1·5	.....	0·3			
	2·4	1·7	−2·3	−1·0	−1·5:	0·4	3·0	0·4	−1·6	−1·5	−0·6	0·0	.....	·007	
660	0·6	0·9	2·8	1·9	1·3	0·9	−0·1	0·8	2·4	2·1	.....	1·4			
	0·9	−0·1	3·5	3·3	1·8	1·9	−0·8	0·6	3·0	3·9	2·0	1·8	0·1	·042	·025
661	.....	.....	0·4	.....	0·4	.....	.....	.....	.....	.....	.....	−0·2			
	.....	.....	0·0	0·0	−0·2	.....	.....	.....	.....	.....	.....	−0·4	−0·3	·012	
662	.....	.....	3·2	.....	−0·7	.....	.....	.....	.....	.....	.....	1·4:			
	.....	.....	2·7	−0·3	0·3	.....	.....	.....	.....	.....	.....	1·1:	.....	·011	
663	.....	.....	5·2	4·1	4·4	.....	.....	.....	.....	.....	.....	4·4			
	6·0:	.....	3·3	3·2	3·9	.....	.....	.....	.....	.....	.....	4·0	4·2	·014	·029
664	.....	.....	0·1	.....	2·2	.....	.....	.....	.....	.....	.....	1·3			
	.....	.....	0·6	2·2	1·4	.....	.....	.....	.....	.....	.....	1·4	1·5	·017	·013
665	.....	.....	0·6	.....	2·5	.....	.....	.....	.....	.....	.....	1·6			
	.....	.....	1·2	.....	2·5	.....	.....	.....	.....	.....	.....	1·8	1·4	·032	·013
666	1·7	1·8	.....	0·8	0·0	1·3	1·7	3·5	1·6	2·4	.....	1·5			
	1·8	1·8	0·1	0·1	2·0	3·4	0·4	1·2	0·6	2·2	−0·1	1·3	.....	·012	
667	.....	.....	0·8	.....	3·0	.....	.....	.....	.....	.....	.....	2·8			
	.....	.....	2·9	3·1	3·4	.....	.....	.....	.....	.....	.....	2·9	.....	·019	
668	3·9	4·3	1·4	2·5	1·8	.....	.....	.....	.....	.....	.....	2·7			
	2·8	2·6	−0·3	0·4	0·5	5·3	.....	.....	.....	.....	.....	2·2	.....	·026	
669	1·1	0·3	.....	0·8	.....	0·2	−0·1	0·1	−0·2	0·5	.....	0·4			
	0·2	0·2	−0·6	−0·8	.....	1·5	0·2	0·0	−0·6	0·4	−0·1	0·2	.....	·010	
670	0·0	0·0	2·3	0·6	1·0	.....	.....	.....	.....	.....	.....	1·3			
	1·2	1·0	0·3	.....	1·4	.....	.....	.....	.....	.....	.....	1·3	.....	·012	
671	1·8	0·6	2·2	2·3	.....	3·5	1·7	1·6	1·6	3·0	.....	1·9			
	2·0	−0·1	2·2	1·2	2·2	1·9	1·0	0·9	2·3	2·7	2·8	1·8	−0·2	·064	·056
672	0·5	0·6	0·8	1·6	−0·2	0·7	0·5	0·0	−1·0	1·9	.....	0·7			
	1·8	1·4	1·5	0·2	0·8	2·1	2·4	3·2	1·1	2·8	.....	1·9	.....	·014	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
673	Boss 4010	λ Serpentis	15 41·6	07 40	4·4	G1	·240	−51·1	5·1 5·8	4·0 4·1	6·0 5·8
674	Boss 4015	κ Serpentis	15 44·2	18 27	4·3	K9	·108	−21·2	....	....	... ...
675	Boss 4024	δ Cor. Bor.	15 45·4	26 23	4·7	G5	·106	− 1·4	0·4 1·6	1·9 0·9	....
676	Boss 4031	ρ Serpentis	15 46·9	21 17	4·9	K7	·045	−42·9	....	....	....
677	Boss 4032	κ Cor. Bor.	15 47·5	35 59	4·8	K1	·363	− 5·5	4·1 3·8	1·5 2·4	....
678	Boss 4040	39 Serpentis	15 48·5	13 31	6·2	G2	·584	+55·1	5·9 5·0	5·8 6·1	6·3 5·3
679	Boss 4042	χ Herculis	15 49·2	42 44	4·6	F8	·763	−38·1	5·3 5·9	3·9 4·6	5·0 4·8
680	Boss 4048	.....	15 50·2	20 36	5·8	K4	·080	−45·2	....	....	....
681	Boss 4055	γ Serpentis	15 51·8	15 59	3·9	F6	1·332	+24·2	5·3 4·4	4·8 5·4	4·7 3·7
682	Boss 4057	λ Cor Bor.	15 52·1	38 14	5·5	F1*n*	·087	+ 5·2	1·3 1·4	0·9 1·9	2·2 1·1
683	Boss 4060	.....	15 52·6	14 42	5·7	K3	·131	−52·6	2·0 0·6	1·2 1·4	....
684	Boss 4063	ε Cor. Bor.	15 53·4	27 10	4·2	K1	·106	−12·8	−0·3 1·0	2·2 3·0	.. ..
685	Boss 4075	5 Herculis	15 56·7	18 06	5·3	G6	·153	+ 0·4	2·4 2·6	1·2 1·5	....
686	Boss 4077	ρ Cor. Bor.	15 57·2	33 37	5·4	F9	·808	+33·4	6·3 5·6	4·9 4·6	4·8 5·0
687	Boss 4090	θ Draconis	16 00·0	58 50	4·1	F7	·458	+ 7·9	3·4 2·8	2·6 3·2	2·9 2·9
688	.....	Groom. 2305	16 01·5	39 24	6·8	G9	·571	−42·1	6·1 4·8	6·2 5·8	....
689	H. R. 6005	.....	16 03·0	22 06	6·3	K5	.....	.....	....	....	....
690	Boss 4101	.....	16 03·6	17 19	5·3	G3	·041	+ 7·7	2·1 1·9	0·9 0·6	2·7 1·2
691	.....	Lal. 29437	16 04·3	06 41	6·0	K1	·760	+11·9	3·3 2·6	4·7 3·6	....
692	Boss 4108	τ Cor. Bor.	16 05·3	36 45	4·9	K0	·325	+ 5·8	2·7 1·9	2·0 2·6	....
693	Boss 4129	.....	16 08·1	36 41	5·7	K4	·039	− 5·8	−1·1 0·4	0·4	....
694	Boss 4130	9 Herculis	16 08·3	05 16	5·6	K6	·049	+13·3	....	....	....
695	H. R. 6052	.....	16 08·7	26 56	6·4	F4	.....	.....	3·3 2·2	5·1 3·8	3·2 3·0
696	Boss 4134	δ Ophiuchi	16 09·1	−03 26	3·0	K8	·159	− 4·8	−0·2	....	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
673	3·0	.....	3·7	5·4	5·6	.....	.....	.....	.....	.....	.....	**4·7**			
	2·5	.....	3·8	5·1	5·3	.....	.....	.....	.....	.....	.....	**4·6**	4·4	**·112**	·086
674	0·8	.....	.....	−0·6	.....	−1·1	0·6	1·3	0·5	0·1	−0·5	**0·1**			
	0·2	0·8	−0·8	−0·8	.....	.....	0·2	1·2	−1·3	0·0	−0·5	**−0·1**	0·0	**·014**	
675	4·4	3·1	1·6	1·8	3·8	0·3	2·0	1·3	−0·6	0·5	.....	**1·7**			
	3·6	2·8	2·2	2·6	1·9	−0·1	2·2	2·3	.....	.....	.....	**2·0**	1·7	**·027**	·013
676	.....	.....	.....	.....	.....	.....	1·0	0·3	−0·5	0·5	.....	**0·4**:			
	2·4	0·8	.....	.....	.....	.....	0·8	1·2	−0·2	1·0	−1·1	**0·1**:	0·7	**·012**	
677	3·3	2·8	1·6	3·3	2·2	3·2	2·5	2·8	.....	.....	.....	**2·7**			
	3·0	1·5	1·8	3·3	2·0	3·5	3·2	3·1	2·0	4·5	.....	**2·7**	1·6	**·038**	·030
678	6·5	.....	3·5	5·0	3·2	.....	.....	.....	.....	.....	.....	**5·2**			
	5·7	4·2	2·0	3·1	3·8	.....	.....	.....	.....	.....	.....	**4·4**	5·1	**·053**	·031
679	4·4	.....	4·7	4·5	4·7	.....	.....	.....	.....	.....	.....	**4·6**			
	4·0	.....	4·5	3·5	3·2	.....	.....	.....	.....	.....	.....	**4·4**	4·2	**·096**	·099
680	.....	−1·4	.....	−1·0	.....	−0·3	−2·7	−2·7	−2·5	−2·8	.....	**−1·9**			
	−0·8	−2·6	−2·3	−0·4	.....	.....	−0·7	−2·1	−2·6	−3·2	−1·9	**−1·8**	0·8	**·003**	·040
681	.....	.....	4·5	4·3	3·1	.....	.....	.....	.....	.....	.....	**4·4**			
	.....	.....	2·9	4·2	4·1	.....	.....	.....	.....	.....	.....	**4·1**	4·3	**·118**	·063
682	.....	.....	1·2	.....	2·3	.....	.....	.....	.....	.....	.....	**1·6**			
	.....	.....	1·8	2·4	1·7	.....	.....	.....	.....	.....	.....	**1·7**	.....	**·017**	
683	3·1	1·0	−0·8	−1·3	0·7	0·5	−1·4	0·6	−0·3	0·3	.....	**0·5**			
	1·7	0·6	−2·2	−1·1	−0·6	0·5	−0·3	2·0	−0·5	1·4	0·4	**0·2**	.....	**·009**	
684	1·5	2·2	0·7	−0·4	2·8	0·5	1·4	1·3	−0·3	−0·4	.....	**0·9**			
	1·7	0·8	1·8	0·0	1·5	1·9	1·4	0·6	−0·8	0·5	.....	**1·1**	0·9	**·023**	
685	1·3	3·1	0·7	1·3	0·5	1·1	0·0	0·2	−0·6	0·8	.....	**1·0**			
	0·5	2·0	1·3	−0·8	1·6	1·5	0·9	1·0	−0·2	0·0	.....	**1·0**	0·7	**·014**	
686	3·8	.....	4·1	4·2	4·4	.....	.....	.....	.....	.....	.....	**4·6**			
	4·3	.....	3·0	3·6	4·8	.....	.....	.....	.....	.....	.....	**4·4**	3·6	**·066**	·035
687	2·3	.....	1·8	2·8	2·8	.....	.....	.....	.....	.....	.....	**2·7**			
	3·2	.....	2·6	3·4	2·9	.....	.....	.....	.....	.....	.....	**3·0**	3·2	**·057**	·066
688	7·5	6·9	.....	5·7	5·6	.....	.....	.....	.....	.....	.....	**6·3**			
	7·3	6·8	3·0	4·0	6·7	6·3	7·0	7·7	.....	.....	.....	**5·9**	6·1	**·072**	·069
689	0·8	.....	.....	.....	.....	.....	−0·7	−1·2	−0·7	−0·9	.....	**−0·5**:			
	−2·0	−1·7	.....	.....	.....	.....	−1·3	−1·2	−3·0	−0·7	−1·8	**−1·7**:	.....	**·003**	
690	.....	.....	2·4	2·9	2·1	.....	.....	.....	.....	.....	.....	**2·2**			
	3·1	2·0	1·2	0·0	2·0	0·4	.....	.....	.....	.....	.....	**1·4**	−0·2	**·020**	
691	3·3	2·7	3·4	4·0	5·1	.....	.....	.....	.....	.....	.....	**3·8**			
	2·2	2·2	1·6	0·4	.....	2·1	3·4	3·4	2·3	2·8	.....	**2·4**	4·4	**·026**	·014
692	3·0	2·4	2·2	1·3	3·1	1·6	2·3	1·8	2·6	3·0	.....	**2·3**			
	2·3	1·9	2·9	1·5	1·8	2·0	1·4	2·0	0·6	2·0	.....	**2·0**	2·8	**·028**	·044
693	0·8	0·3	.....	−2·0	.....	−0·3	0·9	0·6	−0·9	0·1	.....	**−0·1**			
	1·0	−0·7	−0·9	−0·5	−0·7	0·3	1·3	1·6	−0·8	0·2	1·0	**0·2**	.....	**·007**	
694	.....	.....	.....	.....	.....	.....	1·5	0·9	0·0	−0·3	.....	**0·5**			
	0·7	1·0	.....	.....	.....	.....	1·9	1·4	0·9	0·6	1·3	**1·1**	0·8	**·011**	
695	.....	.....	3·2	3·0	4·0	.....	.....	.....	.....	.....	.....	**3·6**			
	.....	.....	2·5	2·5	4·8	.....	.....	.....	.....	.....	.....	**3·1**	.....	**·025**	
696	1·3	−1·0	.....	0·3	.....	−0·2	0·8	0·6	0·3	−1·0	.....	**0·1**			
	1·2	−0·5	−0·1	0·5	0·2	−0·2	−0·3	−0·2	−0·8	0·0	−0·1	**0·0**	0·3	**·026**	·045

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
697	H. R. 6057	.....	16 09·3	06 09	6·4	K3:	.....	.....	.....	.....	.....
									.....	.....	.....
698	.....	σ^1Cor. Bor. ft.	16 10·9	34 07	6·7	F9	·299	+ 0·2	2·7	5·0	3·5
									4·0	4·2	4·1
699	Boss 4138	σ^2 Cor. Bor.br.	16 10·9	34 07	6·5†	F8	·302	− 6·7	4·7	4·5	3·1
									3·1	3·8	2·4
700	Boss 4142	15 Herculis	16 12·0	23 22	6·6	G6	·025	+33·1	0·6	2·3	.....
									−0·3	2·3	.....
701	Boss 4154	19 Herculis	16 14·3	26 08	6·6	G4	·008	+ 9·9	0·8	1·8	1·6
									1·5	1·4	0·7
702	H. R. 6090	.....	16 16·4	49 17	6·2	K6	.....	.....	0·3	.....	.....
									1·2	.....	.....
703	Boss 4161	.....	16 16·5	39 57	5·5	F2	·108	−12·4	1·8	3·6	3·0
									2·8	3·0	2·4
704	Boss 4163	σ Serpentis	16 17·0	01 16	4·8	A9	·169	−29·2	3·0	2·3	1·3
									1·8	2·0	0·9
705	Boss 4165	γ Herculis	16 17·5	19 23	3·8	A6n	·059	−21·0	1·4	.....	0·0
									1·2	.....	0·5
706	Boss 4169	ξ Cor. Bor.	16 18·2	31 07	4·7	K0	·131	− 9·5	2·3	0·9	.....
									1·8	0·0	.....
707	Boss 4181	η Ursae Min.	16 20·4	75 59	5·0	F0	·261	+ 3·5	1·5	1·0	2·2
									1·3	2·2	2·3
708	Boss 4186	.....	16 22·0	69 20	5·4	K0	·028	+ 6·5	1·1	1·2	.....
									2·2	2·2	.....
709	Boss 4191	.....	16 22·5	61 56	5·6	G9	·046	− 7·5	1·2	2·0	.....
									0·4	.....	.....
710	Boss 4192	η Draconis	16 22·6	61 44	2·9	G5	·062	+ 2·4	0·9	0·3	.....
									2·5	1·0	.....
711	.....	B.D. 51° 2097	16 23·0	51 22	7·3	F1	.....	.....	3·0	3·1	4·0
									2·9	3·4	2·4
712	Boss 4193	α Scorpii	16 23·3	−26 13	1·2	M2	·032	+ 6·5	.....	.....	.....
									.....	.....	.....
713	Boss 4195	.....	16 23·5	00 52	5·5	K6	·075	+24·2	.....	.....	.....
									.....	.....	.....
714	Boss 4204	β Herculis	16 25·9	21 42	2·8	G4	·104	− 7·1	0·5	−1·2	2·7
									1·9	−0·8	3·4
715	H. R. 6150	.....	16 26·1	51 39	6·4	K1	.....	.....	.....	0·9	.....
									−1·1	2·4	.....
716	Boss 4207	.....	16 26·2	20 42	5·3	G5	·092	+35·8	.....	−3·1	.....
									0·8	.....	.....
717	Boss 4222	12 Ophiuchi	16 31·1	−02 06	5·9	K0	·547	+ 1·2	.....	5·7	.....
									.....	5·5	.....
718	Boss 4240	.....	16 36·0	56 13	5·4	G8	·084	− 1·8	2·1	2·8	.....
									1·9	2·0	.....
719	Boss 4242	.....	16 36·0	49 07	5·1	M3	·041	−37·7	0·1	.....	.....
									0·3	.....	.....
720	Boss 4244	14 Ophiuchi	16 36·7	01 21	5·9	F2	·120	−30·0	0·3	3·9	2·0
									1·8	3·0	1·0

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
697	.....	.....	.....	0·6	.....	.....	−1·8	−0·1	0·6	1·4	.....	0·1			
	0·6	0·4	.....	−0·1	.....	.....	−0·9	0·1	−0·8	0·2	0·2	0·0	.....	·005	
698	5·6	.....	4·4	2·7	3·0	.....	.....	.....	.....	.....	.....	3·9			
	6·5	.....	4·8	2·9	4·4	.....	.....	.....	.....	.....	.....	4·4	4·2	·031	·044
699	6·5	.....	3·8	4·8	3·8	.....	.....	.....	.....	.....	.....	4·4			
	5·1	.....	4·6	4·4	3·2	.....	.....	.....	.....	.....	.....	3·8	3·7	·033	·044
700	0·6	−0·4	0·7	0·8	0·6	−0·4	0·0	−0·3	−0·7	0·9	.....	0·4			
	1·5	1·6	0·3	−1·1	0·6	0·0	−0·2	.....	.....	0·0	.....	0·5	.....	·006	
701	−0·4	0·7	0·6	0·6	1·0	.....	.....	.....	.....	.....	.....	0·8			
	0·8	−0·3	1·6	−2·1	2·2	0·2	.....	.....	.....	.....	.....	0·6	.....	·007	
702	−0·2	.....	.....	−0·5	.....	0·2	−0·5	1·3	0·4	0·5	.....	0·2			
	1·6	1·0	−1·0	−0·2	0·3	1·9	0·6	1·4	−0·3	0·6	−0·2	0·6	.....	·007	
703	.....	.....	2·5	.....	3·3	.....	.....	.....	.....	.....	.....	2·8			
	.....	.....	0·2	2·8	3·5	.....	.....	.....	.....	.....	.....	2·4	.....	·026	
704	.....	.....	1·1	.....	1·2	.....	.....	.....	.....	.....	.....	1·8			
	.....	.....	2·2	1·3	3·0	.....	.....	.....	.....	.....	.....	1·9	1·5	·026	·031
705	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·7:			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·8	1·4	·025	·017
706	2·2	1·9	2·4	0·9	4·1	−0·2	2·7	.....	.....	2·3	.....	1·9			
	2·0	0·8	1·9	2·7	3·1	1·5	0·6	0·3	.....	1·3	.....	1·5	0·7	·025	·014
707	.....	.....	0·6	....	3·0	.....	.....	.....	.....	.....	.....	1·7			
	.....	.....	1·8	2·2	2·8	.....	.....	.....	.....	.....	.....	2·1	1·7	·024	
708	0·5	0·3	0·8	1·0	−0·2	2·3	0·8	0·4	0·1	1·9	.....	0·9			
	1·4	0·1	2·1	1·1	1·7	2·5	0·8	0·3	1·4	2·5	0·4	1·4	.....	·014	
709	0·8	1·4	0·8	−0·6	−0·7	−0·7	−0·6	−0·2	−0·5	1·0	.....	0·3			
	.....	0·5	1·1	−0·2	0·1	−0·7	0·5	.....	1·0	1·1	.....	0·4	.....	·009	
710	1·9	.....	2·4	4·3	0·2	1·8	.....	.....	.....	.....	.....	1·7			
	0·8	2·3	3·8	4·0	1·2	0·5	0·4	1·1	.....	.....	.....	1·8	0·7	·059	·019
711	.....	.....	3·3	.....	3·4	.....	.....	.....	.....	.....	.....	3·4			
	.....	.....	2·5	2·6	2·4	.....	.....	.....	.....	.....	.....	2·7	.....	·014	
712	.....	.....	.....	−4·4	.....	−4·7	−3·7	−4·4	−4·6	−2·5	−2·5	−3·8			
	.....	−2·6	−4·5	−3·9	.....	−3·7	−0·9	−3·8	−3·7	−2·5	−2·4	−3·1	−2·7	·012	·029
713	0·8	0·0	.....	0·0	.....	−1·8	0·4	1·6	0·8	1·9	.....	0·4			
	1·8	−0·5	−0·3	0·3	.....	−1·5	−0·1	0·6	3·2	2·7	3·2	0·8	0·5	·010	·016
714	.....	.....	−0·2	1·9	0·4	.....	.....	.....	.....	.....	.....	0·7			
	0·4	0·2	0·6	0·6	3·6	0·5	0·1	0·7	.....	.....	.....	1·0	−1·0	·041	·020
715	1·3	1·4	−0·7	0·5	.....	−0·2	0·5	0·2	−0·9	1·3	.....	0·4			
	1·6	−0·4	−0·9	−0·9	−1·3	1·6	2·4	1·4	0·6	2·0	.....	0·6	.....	·007	
716	0·6	−2·9	−0·9	−3·6	−2·0	−1·2	.....	−2·6	−3·0	−3·0	.....	−2·2			
	−1·9	−1·2	0·2	−2·5	−2·7	−1·8	−0·2	−0·9	−1·1	−1·8	.....	−1·2	.....	·004	
717	6·4	6·0	4·1	3·5	.....	.....	.....	.....	.....	.....	.....	5·1			
	6·5	5·3	.....	.....	7·0	6·1	5·2	5·8	5·0	6·1	.....	5·7	5·6	·080	·088
718	2·5	−0·2	1·3	2·0	0·4	1·3	−0·8	0·9	−0·3	1·5	.....	1·0			
	1·2	1·2	1·5	0·8	1·6	1·5	1·3	0·7	0·6	0·8	.....	1·3	.....	·014	
719	.....	.....	.....	−0·2	.....	−0·1	0·1	−0·1	−1·2	−0·5	−1·2	−0·4			
	.....	−0·2	0·0	0·8	.....	−0·8	−2·4	−1·5	−1·7	−0·3	−1·6	−0·7	−0·3	·007	
720	.....	.....	0·8	.....	1·5	.....	.....	.....	.....	.....	.....	1·7			
	.....	.....	−1·1	1·9	2·5	.....	.....	.....	.....	.....	.....	1·5	.....	·014	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
721	Boss 4246	ζ Herculis br.	16 37·5	31 47	3·0	G0	·602	−51·0	3·7 4·8	3·0 3·2	3·7 3·2
722	Boss 4255	ζ Herculis	16 39·5	39 07	3·6	G6	·101	+27·9	1·8 2·4	0·3 0·9	....
723	Boss 4257	41 Herculis	16 40·1	06 17	6·7	G7	·350	+11·0	3·9 2·8	4·6 4·4	....
724	Boss 4258	.....	16 40·1	34 13	5·9	F2*n*	·087	+ 7·9	0·0 1·3	4·1 2·8	−1·3 0·4
725	Boss 4262	.....	16 40·9	15 56	5·8	M3	·055	− 1·8	....	....	....
726	H. R. 6239	.....	16 43·5	13 46	6·3	G7	.....	.....	1·7 −0·3	0·0 0·4	....
727	Boss 4286	.....	16 46·7	29 59	5·9	K7	·007	+ 7·1	....	....	....
728	H. R. 6264	.....	16 47·3	42 04	6·3	K3	.....	.....	....	..... 2·7	....
729	Boss 4305	.....	16 50·4	43 00	6·7	F9	·349	+24·7	6·0 5·2	5·0 4·2	4·2 4·4
730	Boss 4307	.....	16 50·6	21 08	5·5	G7	·062	+18·7	−0·1 0·6	1·2 2·0	....
731	Boss 4310	56 Herculis	16 50·9	25 54	6·3	G7	·032	+18·9	1·2 −0·2	0·4 2·3	....
732	Boss 4311	54 Herculis	16 51·0	18 35	5·6	K6	·102	+30·3	1·9 1·6	....	....
733	Boss 4315	κ Ophiuchi	16 52·9	09 32	3·4	K3	·290	−37·0	3·9 3·6	1·2 0·6	....
734	H. R. 6313	.....	16 54·7	42 39	6·4	K4			....	....	....
735	Boss 4322	19 Draconis	16 55·4	65 17	4·8	F7	·255	− 6·6	3·3 4·0	3·8 3·9	4·5 4·4
736	Boss 4329	.....	16 56·7	22 47	5·7	K2	·027	+30·2	....	..... −1·5	....
737	H. R. 6328	.....	16 57·1	27 21	6·4	F5	.....	.....	5·8 4·2	2·8 4·4	2·2 3·0
738	Boss 4336	.....	16 58·6	14 14	5·1	M2	·071	+59·6	....	....	....
739	.....	Lal. 31132	16 59·8	47 11	6·7	K0	·856	−27·4	5·1 4·1	5·0 5·1	....
740	.....	Lal. 31065	17 00·2	00 51	5·9	G0	·321	+ 2·0	2·8 3·7	5·0 6·0	7·4 4·7
741	H. R. 6360	.....	17 01·6	64 45	6·1	K0	.....	.....	0·3 2·2	..... 1·6	....
742	Boss 4350	33 Ophiuchi	17 02·1	22 13	5·7	K6	·118	−77·9	....	....	....
743	Boss 4351	.....	17 02·1	48 57	6·3	K0	·090	+30·7	2·2 2·5	2·7 2·7	....
744	Boss 4358	.....	17 04·5	36 04	5·4	A5	·027	−12·7	0·4 1·9	1·4 1·8	3·0 1·5

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No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt. W. M	Victoria π	Trig. π
721	1·5	.....	4·6	3·8	3·3	.....	.....	.....	.....	.....	.....	**3·4**			
	1·0	.....	3·8	3·9	1·8	.....	.....	.....	.....	.....	.....	**3·1**	2·4	**·112**	·114
722	0·6	0·3	0·8	2·5	0·7	0·7	0·8	2·2	0·8	1·5	.....	**1·1**			
	2·1	1·4	2·0	2·2	0·0	−0·3	−0·6	−0·1	.....	.....	.....	**1·0**	0·9	**·031**	·056
723	4·2	2·7	1·2	.....	.....	.....	.....	.....	.....	.....	.....	**3·3**			
	2·4	1·6	0·3	0·8	.....	.....	1·3	3·5	.....	2·0	.....	**2·1:**	4·7	**·016**	·024
724	.....	.....	−0·2	.....	1·9	.....	.....	.....	.....	.....	.....	**0·9**			
	.....	.....	−1·0	.....	1·4	.....	.....	.....	.....	.....	.....	**1·0**	.....	**·010**	
725	.....	.....	.....	0·7	.....	−2·3	1·5	0·6	−0·8	−0·7	0·0	**−0·1**			
	.....	0·0	−1·0	−0·3	.....	−1·3	−0·9	−0·5	−1·0	−1·2	0·0	**−0·7**	0·8	**·006**	·022
726	.....	.....	1·2	1·3	−0·4	1·5	1·2	0·9	0·8	1·3	.....	**1·0**			
	2·0	0·2	−0·6	−0·6	0·5	1·8	.....	.....	.....	2·0	.....	**0·6**	.....	**·008**	
727	.....	1·3	−1·0	−1·0	.....	−1·0	−1·4	−0·2	−0·8	−0·8	.....	**−0·6**			
	1·0	0·7	−1·1	−1·0	.....	.....	0·4	0·4	0·2	0·0	0·9	**0·2**	.....	**·006**	
728	3·2	2·7	.....	−0·8	−0·7	0·0	2·7	3·5	1·6	0·7	.....	**1·4**			
	2·6	1·8	−0·9	−0·8	0·9	0·8	2·9	.....	.....	1·0	1·5	**1·2**	.....	**·010**	
729	3·7	.....	2·5	4·1	2·8	.....	.....	.....	.....	.....	.....	**4·0**			
	3·3	.....	.....	2·6	2·6	.....	.....	.....	.....	.....	.....	**3·7**	4·0	**·027**	·031
730	.....	.....	0·3	−1·3	−2·2	−1·4	1·2	0·4	−0·3	0·1	.....	**−0·2**			
	0·1	2·0	1·0	0·1	−0·5	−0·9	0·6	0·4	0·4	0·5	.....	**0·5**	0·9	**·009**	·001
731	2·1	2·8	−0·9	−0·4	−0·4	−0·4	.....	.....	.....	.....	.....	**0·5**			
	1·2	1·1	1·6	−1·4	−1·7	−0·8	−2·1	.....	0·9	0·8	.....	**0·2**	.....	**·006**	
732	.....	.....	.....	0·3	.....	0·5	−0·4	0·0	−0·3	0·7	.....	**0·4**			
	−0·4	0·5	−0·2	0·4	0·0	0·9	0·2	0·4	0·2	0·9	0·4	**0·4**	.....	**·009**	·008
733	3·3	1·6	2·6	4·8	0·8	3·4	2·4	2·6	0·2	3·6	.....	**2·5**			
	0·6	1·8	0·6	2·6	1·5	4·5	2·9	1·2	0·6	1·9	0·6	**1·8**	0·6	**·057**	
734	0·8	2·0	.....	0·0	.....	−0·3	−1·0	2·6	0·0	−1·0	.....	**0·4**			
	.....	.....	−1·8	−0·2	1·4	0·6	−0·6	0·4	−2·1	0·1	−1·9	**−0·5**	.....	**·005**	
735	4·9	.....	4·7	4·9	4·0	.....	.....	.....	.....	.....	.....	**4·3**			
	4·5	.....	5·1	5·0	4·2	.....	.....	.....	.....	.....	.....	**4·4**	3·6	**·082**	·087
736	0·5	0·0	.....	−0·8	.....	.....	−2·2	−2·3	−2·3	−1·3	.....	**−1·2:**			
	.....	−0·8	.....	.....	.....	.....	−0·3	−2·4	−1·2	−0·5	0·0	**−1·0:**	.....	**·004**	
737	.....	.....	5·5	.....	3·0	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	3·0	3·8	4·0	.....	.....	.....	.....	.....	.....	**3·7**	.....	**·030**	
738	.....	.....	.....	0·7	.....	−0·8	−0·8	−0·7	−0·5	−0·8	−1·0	**−0·6**			
	.....	−1·5	0·6	1·0	.....	−0·9	−2·5	−1·0	−1·2	−1·0	−0·6	**−0·8**	−0·1	**·007**	
739	6·6	.....	.....	6·3	5·1	.....	.....	.....	.....	.....	.....	**5·6**			
	6·5	5·6	.....	5·1	6·4	6·3	3·9	4·7	7·4	5·5	.....	**5·5**	6·0	**·059**	·090
740	1·0	.....	6·7	4·1	4·4	.....	.....	.....	.....	.....	.....	**4·5**			
	3·3	5·5	4·6	4·0	.....	.....	.....	.....	.....	.....	.....	**4·5**	4·1	**·053**	·039
741	1·2	2·7	0·2	1·4	0·8	2·2	2·9	1·8	1·6	2·7	.....	**1·6**			
	0·3	0·5	1·3	2·3	3·4	2·5	2·7	2·7	2·3	2·8	2·2	**2·1**	.....	**·014**	
742	.....	.....	.....	−0·8	.....	.....	−0·7	0·7	0·6	1·0	.....	**0·2**			
	.....	−0·6	−1·5	−1·0	.....	.....	−0·1	0·6	0·9	1·3	0·4	**0·0**	.....	**·007**	
743	2·6	.....	3·2	1·6	2·2	2·6	3·3	1·0	0 8	3·0	.....	**2·3**			
	2·4	1·4	1·2	−0·2	0·5	2·3	1·4	1·9	0·2	2·5	.....	**1·6**	.....	**·013**	
744	.....	.....	5·2	.....	.....	.....	.....	.....	.....	.....	.....	**2·5:**			
	.....	.....	2·4	2·5	1·2	.....	.....	.....	.....	.....	.....	**1·9**	.....	**·023**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
745	Boss 4364	.....	17 06·3	40 54	5·1	K2	·050	−36·6	1·3 1·1	3·5 2·6	....
746	Boss 4373	α Herculis br.	17 10·1	14 30	3·5	M6	·028	−13·6	−2·0 −2·9	....	....
747	Boss 4381	π Herculis	17 11·6	36 55	3·4	K3	·021	− 5·6	0·2 0·4	....	....
748	Boss 4393	.....	17 14·9	28 55	5·8	G9	·048	+ 6·9	−1·0 −1·2	0·4 1·6	....
749	Boss 4400	.....	17 15·9	18 10	5·2	M0	·052	−26·9	....	....	....
750	Boss 4403	72 Herculis	17 16·9	32 36	5·4	F9	1·061	−58·7	4·7 4·0	4·9 4·4	4·1 4·8
751	H. R. 6466	.....	17 17·7	28 51	6·3	F9	.....	.....	2·3 2·0	3·2 2·8	3·9 3·9
752	H. R. 6467	.....	17 17·8	48 17	6·3	F2	.....	.....	3·3 3·2	3·5 5·3	5·6 4·7
753*	Boss 4411	.....	17 18·4	40 05	6·5†	F9	·077	+ 9·5	4·2 3·0	2·1 2·3	2·4 1·7
754	Boss 4416	.....	17 19·9	23 03	5·7	A4	·060	− 1·1	2·8 3·0	3·4 4·2	2·4 2·2
755	H. R. 6488	.....	17 20·7	38 41	6·4	F7*n*	.....	.....	−1·7 −0·5	1·7 1·3	0·5 −2·0
756	Boss 4422	.....	17 21·0	37 02	6·5	G4	·050	+37·9	1·6 1·3	−0·4 0·7	1·4 1·6
757*	Boss 4423	.....	17 21·3	−05 00	5·3†	F2	·100	+16·5	1·2 0·4	1·8 1·1	0·0 0·0
758	H. R. 6499	.....	17 22·0	26 57	6·4	A5	.....	.....	0·1 1·4	2·4 2·7	3·5 2·8
759	Boss 4433	Bu. 8038	17 25·2	−00 58	6·0†	G8	·213	−53·9	6·0 4·8	5·9 6·4	....
760	.....	Lal. 32047	17 25·3	67 24	6·3	K0	·536	−22·5	4·0 6·6	6·7 7·2	....
761	Boss 4437	.....	17 26·4	02 48	5·6	G2	·036	−14·5	3·5 1·4	1·6 0·9	3·0 1·6
762	Boss 4438	λ Herculis	17 26·7	26 11	4·5	K5	·023	− 5·4	−0·2 0·4	3·2 1·8	....
763	Boss 4443	β Draconis	17 28·2	52 23	3·0	G0	·013	− 1·3	−2·4 −2·8	−1·7 −1·2	−0·7 −1·4
764	Boss 4458	ν^1 Draconis n.p.	17 30·2	55 15	5·0	A4	·162	+ 4·0	1·9 1·8	2·9	3·6 3·3
765	Boss 4460	ν^2 Draconis s.f.	17 30·3	55 14	5·0	A4	·169	+ 1·0	2·4 1·3	2·4 3·9	4·1 2·8
766	Boss 4470	26 Draconis	17 33·9	61 58	5·3	G0	·564	+ 4·0	3·9 4·4	5·0 4·4	4·9 4·4
767	Boss 4471	82 Herculis	17 34·0	44 38	5·5	K0	·059	+46·9	1·6 2·2	0·0 1·2	....
768	Boss 4472	.....	17 34·1	02 05	6·4	G8	·051	+16·0	....	3·9 3·3	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
745	1·8	1·1	2·1	0·8	−0·7	0·6	1·4	0·7	−0·4	−0·4	.....	**1·0**			
	1·4	1·3	−1·2	0·0	−0·9	1·1	1·8	1·0	−0·3	−0·2	−0·2	**0·6**	0·8	**·014**	
746	.....	.....	.....	−3·2	.....	−1·7	−3·5	−3·4	−2·2	−2·4	−3·8	**−2·8**			
	.....	−3·7	−4·0	−2·5	.....	−2·8	−4·1	−2·4	−3·2	−3·6	−3·7	**−3·3**	−2·3	**·005**	−·004
747	.....	.....	1·9	0·0	.....	−0·5	0·2	−2·5	0·5	0·1	.....	**0·0**			
	−0·3	−0·5	1·0	0·9	0·4	0·8	0·2	−0·8	0·9	1·3	2·1	**0·5**	0·4	**·023**	·017
748	.....	.....	1·3	0·8	3·8	−1·3	2·8	0·8	0·5	−0·5	.....	**0·8**			
	1·1	2·9	0·8	2·9	2·6	−0·8	2·9	2·4	0·2	−·0·2	.....	**1·3**	0·6	**·011**	·015
749	.....	.....	.....	−1·1	.....	−2·1	−2·5	−2·1	−2·5	−1·2	−2·6	**−2·0**			
	.....	−0·3	−2·1	−2·0	.....	−1·8	−1·2	−3·2	−2·4	−1·0	−0·9	**−1·7**	.....	**·004**	
750	5·5	.....	3·5	4·6	5·5	.....	.....	.....	.....	.....	.....	**4·7**			
	5·6	.....	1·2	1·8	4·7	.....	.....	.....	.....	.....	.....	**3·8**	5·5	**·059**	·087
751	1·4	.....	2·8	3·6	3·3	.....	.....	.....	.....	.....	.....	**2·9**			
	2·9	.....	.....	2·2	3·8	.....	.....	.....	.....	.....	.....	**2·9**	.....	**·021**	
752	.....	.....	3·7	.....	3·5	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	.....	2·4	3·5	.....	.....	.....	.....	.....	.....	**3·8**	.....	**·032**	
753	4·5	.....	3·4	4·1	3·2	.....	.....	.....	.....	.....	.....	**3·4**			
	3·6	.....	2·6	2·2	1·8	.....	.....	.....	.....	.....	.....	**2·7**	.....	**·020**	
754	.....	.....	0·8	.....	2·3	.....	.....	.....	.....	.....	.....	**2·3**			
	.....	.....	2·4	2·2	2·3	.....	.....	.....	.....	.....	.....	**2·7**	.....	·023	
755	2·3	.....	0·9	1·4	1·5	.....	.....	.....	.....	.....	.....	**0·9**			
	4·4	.....	0·6	0·4	1·4	.....	.....	.....	.....	.....	.....	**0·8**:	.....	**·008**	
756	−0·6	.....	0·3	0·6	−0·5	.....	.....	.....	.....	.....	.....	**0·3**			
	2·9	2·5	2·0	−0·8	1·2	−0·1	.....	.....	.....	.....	.....	**1·2**	.....	**·007**	
757	.....	.....	−0·7	.....	0·5	.....	.....	.....	.....	.....	.....	**0·6**			
	.....	.....	1·3	.....	.....	.....	.....	.....	.....	.....	.....	**0·7**	2·1	**·012**	
758	.....	.....	1·5	.....	−0·7	.....	.....	.....	.....	.....	.....	**1·4**			
	.....	.....	1·8	−0·6	0·3	.....	.....	.....	.....	.....	.....	**1·4**	.....	**·010**	
759	5·3	4·1	3·6	4·5	4·5	.....	.....	.....	.....	.....	.....	**4·8**			
	4·6	4·8	4·7	4·4	.....	6·0	5·2	5·6	.....	5·0	.....	**5·1**	5·0	**·062**	·065
760	6·6	6·0	3·8	4·5	5·6	.....	.....	.....	5·1	5·2	.....	**5·3**			
	6·0	5·3	5·8	6·3	4·8:	6·1	5·5	5·8	.....	5·9	.....	**5·9**	5·9	**·072**	·071
761	.....	.....	1·9	2·6	1·7	.....	.....	.....	.....	.....	.....	**2·4**			
	1·0	0·7	2·8	0·0	2·9	0·9	.....	.....	.....	.....	.....	**1·4**	.....	**·018**	
762	2·0	3·3	1·1	0·7	−0·3	1·2	2·5	3·5	0·2	0·2	.....	**1·4**			
	1·3	1·8	2·9	1·2	−1·3	2·4	3·2	2·6	2·0	0·3	1·5	**1·4**	0·4	**·024**	
763	.....	.....	−3·0	−3·2	−1·8	.....	.....	.....	.....	.....	.....	**−2·1**			
	−1·7	.....	−2·2	−3·2	−0·4	.....	.....	.....	.....	.....	.....	**−1·8**	−3·5	**·010**	·005
764	.....	.....	5·0	.....	.....	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	3·1	3·1	2·1	....	....	.....	.....	.....	.....	**2·7**:	.....	**·041**	·019
765	.....	.....	5·2	.....	.....	.....	.....	.....	.....	.....	.....	**3·5**:			
	.....	.....	2·9	3·1	1·2	.....	.....	.....	.....	.....	.....	**2·5**:	.....	**·040**	·019
766	3·0	.....	6·4	6·3	4·8	.....	.....	.....	.....	.....	.....	**4·9**			
	3·6	.....	4·1	4·4	4·2	.....	.....	.....	.....	.....	.....	**4·2**	4·0	**·070**	·084
767	1·8	.....	−0·3	−0·6	0·0	0·7	0·1	0·0	−1·9	−0·6	.....	**0·1**			
	1·0	1·7	−0·6	−1·5	−0·8	2·2	−0·8	0·9	−1·6	−0·3	.....	**0·3**	.....	**·009**	
768	3·8	1·0	2·0	3·0	0·0	.....	1·3	0·0	1·2	2·2	.....	**1·8**			
	1·5	0·2	0·4	0·3	0·5	0·3	.....	.....	0·8	3·2	.....	**1·2**	.....	**·010**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
769	H. R. 6579	.....	17 35·2	32 47	6·4	G5	.....	.....	0·0	1·3 1·7	....
770	H. R. 6584	.....	17 36·2	31 15	6·3	M0	.....	.....	....	....	....
771	Boss 4483	ω Draconis	17 37·5	68 48	4·9	F4	·327	+ 1·8	2·0 2·3	3·2 3·4	1·7 1·2
772	Boss 4486	83 Herculis	17 38·4	24 37	5·6	K5	·129	− 8·2	....	....	....
773	Boss 4487	β Ophiuchi	17 38·5	04 37	2·9	K2	·157	+ 6·4	1·5 2·2	0·6 2·1	....
774	H. R. 6604	.....	17 38·8	14 20	6·2	F4	.....	.....	..... −0·2:	0·9 1·8	2·6 3·4
775	Boss 4488	84 Herculis	17 39·3	24 22	5·7	G4	·128	− 6·4	1·7 1·9	2·8 1·8	2·7 3·4
776	Boss 4497	μ Herculis A	17 42·5	27 47	3·5	G4	·815	+ 4·2	4·7 5·3	3·2 3·0	4·9 .....
777	Boss 4504	ψ Draconis br.	17 43·7	72 12	4·9	F5	·267	+ 4·4	3·0 2·3	2·7 3·4	2·7 1·2
778	Boss 4505	ψ Draconis fr.	17 43·7	72 12	6·1	F7	·278	+ 5·0	5·2 5·1	4·2 5·1	4·9 4·3
779	Boss 4506	.....	17 44·1	20 36	5·8	K0	·024	− 5·8	....	1·9 3·0	....
780	Boss 4507	.....	17 44·4	47 39	6·3	A2	.....	.....	1·8 1·4	2·4 2·4	3·5 3·2
781	Boss 4510	.....	17 46·5	29 21	5·6	K1	·051	+ 5·5	0·0 0·4	1·4 2·1	....
782	Boss 4516	.....	17 48·4	06 08	5·8	F5	·131	−13·4	4·3 3·8	4·8 4·1	4·1 3·6
783	Boss 4518	.....	17 48·8	40 00	6·1	K3	·050	−48·7	0·7 1·0	..... 1·5	....
784	Boss 4522	.....	17 50·0	40 01	5·1	K3	·050	−13·3	−1·1 0·2	2·0 1·9	....
785	Boss 4531	ξ Draconis	17 51·8	56 53	3·9	K3	·126	− 7·2	1·8 2·6	....	....
786	Boss 4535	θ Herculis	17 52·8	37 16	4·0	K1	·008	− 6·6	−3·0 −2·2	−0·5 −1·5	....
787	H. R. 6699	.....	17 53·6	56 00	6·1	F1*n*	.....	.....	1·1 1·7	1·4 1·6	0·0 0·8
788	H. R. 6702	.....	17 53·9	45 23	6·2	M8	.....	.....	....	....	....
789	Boss 4538	ξ Herculis	17 53·9	29 16	3·8	G7	·094	+19·3	0·5 1·6	1·8 1·1	....
790	Boss 4539	35 Draconis	17 53·9	76 59	5·0	F5	·244	− 9·1	3·3 3·3	3·3 2·6	3·8 3·7
791	Boss 4541	γ Draconis	17 54·3	51 30	2·4	K5	·026	− 8·5	0·8 1·0	..... 1·1	....
792	Boss 4542	ν Herculis	17 54·7	30 11	4·5	F3	·006	− 1·6	1·2 2·0	1·5 1·0	1·6 0·3

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
769	2·0	1·6	0·7	1·0	0·4	0·9	0·0	0·9	1·2	1·0	.....	0·9			
	1·3	1·4	0·6	−1·8	.....	1·6	−0·2	0·6	0·9	0·2	.....	0·6	.....	·007	
770	.....	.....	.....	.....	.....	.....	−1·2	−2·0	−0·9	−0·2	.....	−1·1 :			
	−0·4	0·0	.....	.....	.....	.....	−1·0	−1·5	−1·7	−0·4	0·2	−0·7 :	.....	·004	
771	.....	.....	2·3	3·1	2·5	.....	.....	.....	.....	.....	.....	2·5			
	.....	.....	2·1	3·0	4·2	.....	.....	.....	.....	.....	.....	2·7	2·8	·034	·045
772	.....	.....	.....	.....	.....	.....	−1·4	−0·6	−0·2	0·3	.....	−0·5 :			
	−0·8	0·6	.....	.....	.....	.....	−1·2	0·0	−0·2	−1·0	−1·2	−0·5 :	.....	·006	
773	0·5	−0·5	2·3	1·9	2·8	2·0	0·3	0·7	2·4	3·3	.....	1·5			
	0·6	1·1	2·2	1·8	3·1	1·6	1·0	0·9	2·6	2·7	2·5	1·9	0·6	·058	·025
774	.....	.....	1·4	.....	0·7	.....	.....	.....	.....	.....	.....	1·4 :			
	.....	.....	−0·6	1·6	0·6	.....	.....	.....	.....	.....	.....	1·1	.....	·010	
775	3·5	4·9	1·9	2·8	1·1	.....	.....	.....	.....	.....	.....	2·7			
	3·2	3·1	3·0	3·1	1·5	.....	.....	.....	.....	.....	.....	2·7	3·3	·025	·006
776	3·2	0·7	3·9	5·4	4·5	.....	.....	.....	.....	.....	.....	3·8			
	2·8	1·4	2·5	3·4	5·8	.....	.....	.....	.....	.....	.....	3·4	3·7	·105	·105
777	.....	.....	3·4	3·2	2·9	.....	.....	.....	.....	.....	.....	3·0			
	.....	.....	4·3	4·1	3·8	.....	.....	.....	.....	.....	.....	3·2	3·1	·044	·030
778	4·3	.....	5·3	5·6	4·3	.....	.....	.....	.....	.....	.....	4·8			
	3·2	.....	4·4	5·5	4·4	.....	.....	.....	.....	.....	.....	4·6	3·7	·053	·030
779	2·8	1·8	0·4	−0·7	−0·7	0·3	−0·4	1·6	0·8	1·6	.....	0·9			
	1·5	2·4	−1·6	−1·5	0·8	0·8	0·5	1·3	−0·7	2·0	.....	0·8		·010	
780	.....	.....	5·0	.....	.....	.....	.....	.....	.....	.....	.....	3·2			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2·3	.....	·019	
781	2·3	0·2	1·6	−1·3	−1·4	1·2	0·0	0·7	−0·9	0·4	.....	0·4			
	1·2	1·0	−1·3	−0·3	0·4	0·8	−0·1	1·4	0·2	1·1	.....	0·6	.....	·010	
782	.....	.....	5·2	4·7	3·3	.....	.....	.....	.....	.....	.....	4·4			
	.....	.....	3·3	2·5	3·7	.....	.....	.....	.....	.....	.....	3·5	.....	·043	
783	−0·2	−1·4	.....	.....	.....	−0·2	−1·3	−0·8	−0·9	−0·9	.....	−0·6			
	1·0	0·2	−1·7	−1·1	−3·3 :	1·1	−2·9	−0·8	−1·4	−0·5	−1·5	−0·5	.....	·005	
784	2·2	2·4	2·7	−0·4	0·0	−0·5	2·2	1·6	0·2	0·7	.....	1·0			
	1·3	2·1	0·6	−0·1	0·4	1·1	2·6	2·1	−1·2	0·9	−0·7	0·9	.....	·015	
785	1·1	3·1	1·9	2·7	.....	2·7	3·2	2·0	1·2	0·4	.....	2·0			
	2·0	1·4	2·2	1·8	2·6	2·4	2·1	1·2	0·6	0·2	0·6	1·7	0·7	·039	·026
786	−1·4	0·2	1·2	−1·9	0·0	−0·9	−0·4	−2·6	−1·8	−0·5	.....	−1·0			
	−4·6	−0·5	−0·2	0·0	−0·3	−0·6	−0·1	−0·3	−1·6	−1·1	−1·4	−1·1	−0·3	·010	·000
787	.....	.....	0·1	.....	.....	.....	.....	.....	.....	.....	.....	0·6			
	.....	.....	−1·8	.....	2·8	.....	.....	.....	.....	.....	.....	1·0	.....	·009	
788	.....	.....	.....	−2·5	.....	−2·0	−2·4	−2·8	−1·2	−1·2	−1·8	−2·0			
	−4·7	−4·6	.....	−2·3	.....	−3·8	−2·7	−1·0	−2·6	−1·3	−2·7	−2·9	.....	·002	
789	−0·5	0·9	3·4	2·0	0·5	−0·4	1·4	1·2	1·5	1·1	.....	1·1			
	0·8	3·1	3·7	3·8	2·2	1·8	−0·5	0·4	1·3	1·2	.....	1·7	0·9	·033	·025
790	.....	.....	3·5	4·3	2·4	.....	.....	.....	.....	.....	.....	3·4			
	.....	.....	2·7	3·9	2·4	.....	.....	.....	.....	.....	.....	3·1	3·2	·044	·012
791	.....	.....	.....	0·0	.....	0·2	−0·7	1·7	0·2	−0·5	.....	0·2			
	.....	1·0	1·8	1·6	−1·1	0·9	−1·3	−0·3	0·8	−0·3	−0·4	0·4	0·6	·038	·012
792	.....	.....	0·1	2·0	0·9	.....	.....	.....	.....	.....	.....	1·2			
	.....	.....	2·5	3·2	0·2	.....	.....	.....	.....	.....	.....	1·5	−0·2	·023	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
793	Boss 4547	93 Herculis	17 55·6	16 46	4·7	K2	·011	− 3·6	−1·5 0·2	... −0·4	....
794	H. R. 6726	.....	17 56·9	33 14	6·1	K6	.....	.....	....	....	....
795	Boss 4555	.....	17 57·1	45 31	5·9	K7	·044	+ 9·3	..... −1·4:	....	....
796	Boss 4571	70 Ophiuchi br.	18 00·4	02 31	4·3	K1	1·132	+10·3	5·3 3·1	5·2 5·7	....
797		70 Ophiuchi ft.	18 00·4	02 31	6·0	K4	1·132	+10·2	....	....	....
798	H. R. 6754	.....	18 00·6	23 56	6·2	A8	.....	.....	1·4 2·2	2·6 3·6	1·1 1·4
799	H. R. 6763	.....	18 01·3	21 38	6·4	K3			....	....	....
800	Boss 4578	.....	18 01·8	22 13	5·3	M2	·020	− 2·7	−0·6 0·2	....	....
801	Boss 4582	99 Herculis	18 03·2	30 33	5·2	F6	·110	+20·4	4·8 4·6	4·6 4·4	5·1 5·1
802	Boss 4589	.....	18 04·5	43 27	5·1	G6	·066	+ 2·2	0·8 2·4	2·0 1·9	....
803	Boss 4593	.....	18 04·6	36 23	5·7	K2	·211	+13·3	1·3 0·4	3·2 1·8	....
804	Boss 4594	73 Ophiuchi	18 04·6	03 58	5·7	F3*n*	·043	+ 3·4	0·0 0·8	4·3 2·4	0·4 0·8
805	Boss 4595	.....	18 04·8	03 06	5·7	F5	·205	+ 3·6	4·3 3·5	3·6 3·2	2·8 3·2
806	H. R. 6807	.....	18 06·5	36 26	5·9	G7	·012	− 6·1	1·5 1·2	1·7 1·4	....
807	Boss 4602	.....	18 07·5	79 59	6·9†	F6	·134	+15·8	3·9 4·2	3·6 3·8	4·3 4·3
808	Boss 4603	41 Draconis	18 07·5	79 59	5·8	F7	·124	+18·5	3·7 3·3	2·5 2·8	4·5 4·0
809	Boss 4606	.....	18 08·2	31 22	5·0	M5	·016	+18·6	....	....	....
810	Boss 4609	.....	18 08·5	54 15	5·9	G9	·275	+ 1·4	2·6 2·6	3·5 2·6	....
811	H. R. 6820	.....	18 09·0	21 51	6·2	K6	.....	.....	....	....	....
812	H. R. 6831	.....	18 10·8	29 12	6·5	F9	.....	.....	3·7 5·6	3·2 3·6	4·9 5·8
813	Boss 4622	.....	18 13·0	56 34	7·2†	F0	·034	+ 9·4	1·0 2·6	1·3 3·3	2·4 2·3
814	Boss 4626	.....	18 14·3	07 13	5·6	K1	·060	+ 9·6	0·5 2·6	1·9 2·6	....
815	Boss 4629	105 Herculis	18 15·1	24 24	5·5	K2	·019	+ 4·8	....	..... −3·0	....
816	Boss 4638	η Serpentis	18 16·1	−02 55	3·4	G9	·896	+26·3	3·4 2·2	1·4 1·2	....

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No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
793	−0·5	.....	−0·5	−2·0	0·8	1·6	1·1	−0·1	−1·4	−0·2	.....	**−0·3**			
	1·3	.....	−0·9	0·0	2·2	1·9	1·6	1·2	−2·3	−1·0	−1·3	**0·2**	−0·3	·011	
794	0·8	.....	.....	0·3	.....	−2·0	−1·9	−0·6	−0·8	−0·5	.....	**−0·7:**			
	−0·4	0·6	−1·4	−0·2	.....	−0·6	−0·9	−0·6	−2·0	0·1	−0·6	**−0·6**	.....	·004	
795	0·2	−0·5	.....	0·7	.....	−2·2	−2·0	−0·6	−0·9	−0·3	.....	**−0·7**			
	−0·4	−0·4	−0·4	0·3	−0·4	−0·8	−0·8	−1·5	−0·6	−0·2	−0·1	**−0·5**	0·6	·005	·026
796	5·8	4·2	.....	5·6	5·4	.....	.....	.....	6·1	5·8	.....	**5·4**			
	5·0	5·2	4·4	4·6	6·2	5·9	6·3	6·0	5·6	.....	.....	**5·3**	5·8	·162	·187
797	6·8	5·9	.....	.....	.....	.....	.....	.....	6·9	7·5	.....	**6·8:**			
	7·0	6·8	.....	.....	.....	8·7	7·4	7·2	7·7	8·6	7·9	**7·7**	7·2	·178	·187
798	.....	.....	3·0	.....	.....	.....	.....	.....	.....	.....	.....	**2·0**			
	.....	.....	1·6	1·3:	1·2:	.....	.....	.....	.....	.....	.....	**1·9**	.....	·014	
799	1·8	0·0	.....	−0·6	.....	−1·0	−0·5	1·2	0·2	1·0	.....	**0·3**			
	1·3	−0·5	−1·9	−0·8	.....	−0·4:	.....	0·0	0·0	1·0	0·2	**−0·1**	.....	·006	
800	.....	.....	.....	−0·6	.....	−0·3	−0·7	−2·0	−1·2	−0·5	−0·6	**−0·8**			
	.....	−1·1	−2·2	−0·5	.....	−0·7	−0·4	−0·6	−1·4	−0·9	−1·1	**−0·9**	.....	·006	
801	.....	.....	4·1	2·2	3·0	.....	.....	.....	.....	.....	.....	**3·9**			
	2·8	.....	4·2	3·7	2·6	.....	.....	.....	.....	.....	.....	**3·9**	4·4	·056	·045
802	3·9	3·2	1·2	3·5	0·0	2·0	.....	.....	.....	.....	.....	**2·1**			
	1·5	0·6	3·4	2·6	0·4	3·0	.....	.....	.....	.....	.....	**2·0**	.....	·025	
803	2·5	1·0	2·3	0·7	.....	2·3	0·0	2·0	0·8	2·2	.....	**1·7**			
	1·0	0·5	−0·4	−0·2	1·4	2·8	−0·3	.....	.....	2·4	0·0	**0·9**	0·6	·013	
804	.....	.....	2·1	.....	.....	.....	.....	.....	.....	.....	.....	**1·7:**			
	.....	.....	0·5	.....	1·2	.....	.....	.....	.....	.....	.....	**1·1:**	.....	·014	
805	.....	.....	4·3	4·2	2·4	.....	.....	.....	.....	.....	.....	**3·6**			
	.....	.....	3·4	2·5	3·0	.....	.....	.....	.....	.....	.....	**3·1**	2·8	·034	·085
806	3·7	1·6	1·5	1·9	1·3	0·7	1·3	−0·4	0·0	1·7	.....	**1·4**			
	2·6	0·7	0·4	−0·6	0·2	0·3	2·0:	0·5	0·4	1·2	.....	**0·8**	.....	·011	
807	.....	.....	4·1	2·5	3·1	.....	.....	.....	.....	.....	.....	**3·5**			
	4·0	.....	3·8	2·6	3·8	.....	.....	.....	.....	.....	.....	**3·8**	.....	·022	
808	4·3	.....	2·3	3·0	3·4	.....	.....	.....	.....	.....	.....	**3·4**			
	4·0	.....	2·3	2·6	3·8	.....	.....	.....	.....	.....	.....	**3·3**	.....	·032	
809	.....	.....	.....	−2·0	.....	−0·2	0·0	−0·1	1·0	−0·3	−0·6	**−0·3**			
	.....	−1·4	.....	.....	−1·0	−1·2	−0·9	0·2	−1·0	−0·8	−0·9	**−0·9**	−0·1	·008	
810	2·6	1·6	3·2	3·5	4·5	0·4	3·0	2·3	0·8	2·8	.....	**2·6**			
	1·3	1·7	2·6	2·7	2·2	−0·2	1·0	1·8	3·1	3·4	.....	**2·1**	2·8	·019	·012
811	.....	.....	.....	−1·5	.....	.....	−2·6	−0·8	−0·9	−0·9	.....	**−1·3:**			
	1·2	−0·6	.....	−1·7	.....	.....	−0·6	−1·2	−1·6	0·3	−0·2	**−0·6:**	.....	·004	
812	5·9	.....	0·5	4·5	3·0	.....	.....	.....	.....	.....	.....	**3·7**			
	6·0	3·8	0·3	3·6	3·8	.....	.....	.....	.....	.....	.....	**4·1**	.....	·030	
813	1·5	.....	1·9	.....	.....	.....	.....	.....	.....	.....	.....	**1·6**			
	2·0	1·6	2·1	.....	.....	.....	.....	.....	.....	.....	.....	**2·3**	.....	·009	
814	3·2	1·7	2·1	−0·4	0·4	0·6	1·1	2·0	0·8	2·1	.....	**1·3**			
	0·9	0·8	−0·2	−0·3	0·4	1·6	1·9	.....	−0·3	2·6	.....	**1·1**	.....	·013	
815	.....	.....	−0·1	−0·4	.....	.....	−1·2	−1·5	−1·4	−2·0	.....	**−1·1**			
	.....	−0·6	−1·7	0·0	.....	.....	1·0	0·1	−1·2	−1·7	−1·5	**−1·0**	0·2	·005	·002
816	2·4	2·8	2·3	1·4	1·2	0·8	2·8	3·9	3·1	2·7	.....	**2·3**			
	1·9	2·0	1·7	2·6	2·1	1·1	0·5	2·4	2·4	2·0	.....	**1·8**	2·5	·054	·057

80600—8½

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
817	Boss 4639	κ Lyrae	18 16·4	36 01	4·3	K2	·036	− 2·2	0·3 2·4	1·2 1·5	....
818	Boss 4651	.....	18 18·4	17 46	5·5	K2	·069	+ 0·4	2·2 0·4	..... 2·2	....
819	Boss 4653	.....	18 19·0	49 04	5·1	M1	·057	+32·6	....	....	....
820	Boss 4656	109 Herculis	18 19·4	21 43	3·9	K1	·326	−37·3	2·2 3·9	1·2 2·6	....
821	Boss 4660	.....	18 20·8	07 59	5·7	G5	·001	.....	1·2	−1·0 1·0	−1·1 1·2
822	Boss 4669	.....	18 22·1	29 46	5·7	A1	.....	.....	1·5 2·0	2·1 3·3	3·4 3·5
823	Boss 4672	χ Draconis	18 22·9	72 41	3·7	F5	·640	+47·0	5·3 4·6	3·9 5·5	4·3 4·0
824	Boss 4713	.....	18 31·8	06 36	5·4	F1	·147	−12·0	3·3 2·1	3·0 2·6	3·0 1·8
825	H. R. 7008	.....	18 34·7	05 10	6·3	F8	.....	.....	1·7 1·3	1·7 3·5	−2·0 −0·5
826	H. R. 7009	.....	18 34·8	39 35	6·1	M8	.....	.....	−1·2 −1·2	....	....
827	Boss 4742	.....	18 40·1	31 50	5·5	F0	·145	+16·1	1·9 2·8	2·1 2·3	3·5 2·2
828	H. R. 7047	.....	18 40·5	23 29	6·2	F5	.....	.....	2·8 4·1:	2·5 3·0	4·2 4·6
829	Boss 4752	ζ¹ Lyrae	18 41·3	37 30	4·3	A7	·035	+42·2	0·4 −0·2	0·3 2·8	3·0 1·4
830	Boss 4753	110 Herculis	18 41·4	20 27	4·3	F4	·344	+46·4	4·1 3·8	3·2 5·4	4·4 4·6
831	Boss 4756	β Scuti	18 41·9	−04 51	4·5	G6	·024	− 4·9	−1·0 −2·1	0·0 −0·8	....
832	H. R. 7112	.....	18 47·7	28 39	6·4	G9	.....	.....	2·2 −0·2	0·0 2·6	....
833	Boss 4782	.....	18 48·2	73 58	5·4	G5	·082	+16·3	2·0 2·8	2·7 1·8	....
834	Boss 4787	.....	18 49·3	52 50	5·6	G8	·287	+18·6	....	4·5 4·4	....
835	Boss 4790	ο Draconis	18 49·7	59 16	4·8	G8	·089	− 2·3	1·6 0·6	1·6 1·8	....
836	Boss 4795	.....	18 50·4	42 45	6·9	K9	·031	+ 9·6	....	....	....
837	Boss 4797	113 Herculis	18 50·5	22 32	4·6	G2	·004	− 3·8	1·2 1·7	−1·2 0·0	..... 4·5
838	Boss 4798	.....	18 50·6	06 30	5·7	K1	·092	+39·8	0·6 1·0	0·0 2·2	....
839	H.R. 7153	.....	18 52·1	57 20	6·4	K5	.....	.....	−0·2 1·5	....	....
840	Boss 4811	.....	18 52·1	48 44	5·9	F4	·141	+ 7·0	2·3 2·4	2·8 2·1	2·1 1·5

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
817	1·5	1·6	4·0	2·4	0·8	2·8	3·3	3·1	0·8	2·3	.....	**2·0**			
	1·6	1·1	4·8	3·6	3·7	4·0	3·2	2·1	2·0	2·8	1·9	**2·7**	.....	·041	
818	0·3	1·6	1·7	1·9	2·2	0·5	0·2	0·1	1·1	−0·4	.....	**1·0**			
	0·9	−0·4	1·1	0·7	0·1	2·1	1·1	0·6	−0·3	0·9	−0·5	**0·6**	.....	·012	
819	.....	.....	.....	−1·8	−0·5	−0·5	0·7	0·6	−0·4	−1·4	−0·7	**−0·5**			
	.....	−0·8	.....	−1·6	.....	−0·4	−0·9	−1·6	−1·5	−1·3	−1·1	**−1·1**	.....	·007	
820	1·2	2·0	2·0	2·0	0·8	1·3	0·0	1·8	1·6	0·6	.....	**1·4**			
	1·3	1·7	1·1	2·9	1·5	0·5	1·9	2·7	0·9	1·3	.....	**1·9**	1·5	·035	·015
821	−2·5	−0·8	0·6	−0·5	−0·6	.....	.....	.....	.....	.....	.....	**−0·6**			
	−0·1	−0·4	1·0	−1·2	0·2	1·5	.....	.....	.....	.....	.....	**0·4**	−0·8	·007	
822	.....	.....	3·4	.....	0·8	.....	.....	.....	.....	.....	.....	**2·2**			
	.....	.....	2·8	0·0	.....	.....	.....	.....	.....	.....	.....	**2·3**	.....	·020	
823	.....	.....	4·2	4·8	3·2	.....	.....	.....	.....	.....	.....	**4·3**			
	.....	.....	4·3	4·4	3·1	.....	.....	.....	.....	.....	.....	**4·3**	4·1	·132	·105
824	.....	.....	3·1	5·0	4·3	.....	.....	.....	.....	.....	.....	**3·6**			
	.....	.....	2·1	2·4	2·7	.....	.....	.....	.....	.....	.....	**2·3**	1·6	·032	·024
825	.....	.....	1·1	.....	−0·2	.....	.....	.....	.....	.....	.....	**0·5**			
	2·7	.....	0·6	−0·4	.....	.....	.....	.....	.....	.....	.....	**1·2**:	.....	·008	
826	.....	.....	.....	−3·1	.....	−1·8	−3·7	−2·6	−2·7	−3·6	−3·5	**−2·8**			
	.....	−3·6	−3·8	−3·8	.....	−2·4	−2·5	−0·2	−3·0	−1·6	−3·2	**−2·5**	.....	·002	
827	.....	.....	3·3	2·2	1·4	.....	.....	.....	.....	.....	.....	**2·4**			
	.....	.....	2·0	1·6	0·8	.....	.....	.....	.....	.....	.....	**2·0**	.....	·022	
828	3·3	.....	2·1	3·0	3·0	.....	.....	.....	.....	.....	.....	**3·0**			
	3·3:	.....	2·5	0·8	2·4	.....	.....	.....	.....	.....	.....	**3·0**	.....	·023	
829	.....	.....	.....	2·0	0·2	.....	.....	.....	.....	.....	.....	**1·2**			
	.....	.....	3·4	2·2	0·0	.....	.....	.....	.....	.....	.....	**1·6**	.....	·026	
830	.....	.....	4·6	3·1	2·8	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	3·8	3·0	3·9	.....	.....	.....	.....	.....	.....	**4·1**	3·3	·083	·057
831	−2·0	−1·6	−2·2	−2·2	−0·5	0·7	−0·7	−1·6	−2·9	−0·7	.....	**−1·2**			
	−2·3	−0·8	0·6	−1·3	1·4	0·3	0·9	−0·2	−0·9	−0·1	.....	**−0·4**	.....	·009	
832	0·0	1·2	0·4	0·7	1·7	1·0	2·5	−0·2	−1·9	0·5	.....	**0·7**			
	0·8	1·7	−0·9	−1·4	.....	0·9	1·0	−1·0	−1·6	0·4	.....	**0·2**	.....	·006	
833	1·7	1·4	2·4	1·6	0·2	1·3	.....	.....	.....	.....	.....	**1·7**			
	0·4	0·7	1·6	−0·4	0·8	0·5	.....	.....	.....	.....	.....	**1·0**	.....	·016	
834	4·1	4·3	3·9	.....	.....	.....	.....	.....	.....	.....	.....	**4·2**:			
	3·6	4·8	2·6	.....	.....	.....	.....	.....	.....	.....	.....	**3·8**:	3·2	·048	·048
835	−1·1	1·4	3·0	1·7	0·8	0·1	−0·4	−0·1	−0·4	−1·3	.....	**0·6**			
	0·2	0·8	2·4	2·0	0·2	−0·8	−0·9	0·5	0·2	−0·3	.....	**0·5**	−0·5	·014	·028
836	.....	.....	.....	−0·2	.....	.....	−1·3	−1·5	−1·9	−1·5	.....	**−1·3**:			
	−0·6	−1·6	.....	.....	.....	.....	−0·3	0·8	−2·2	−0·4	−0·4	**−0·7**:	.....	·003	
837	−0·4	.....	1·1	0·8	1·1	.....	.....	.....	.....	.....	.....	**0·4**			
	−0·1	0·3	1·5	0·4	.....	1·4	.....	.....	.....	.....	.....	**1·2**	1·7	·017	
838	2·3	3·0	0·5	1·0	.....	0·1	1·6	2·0	0·0	1·2	.....	**1·1**			
	2·1	0·8	−0·9	0·0	−1·7	0·8	−0·4	0·6	0·9	0·7	.....	**0·5**	.....	·010	
839	0·8	.....	.....	0·3	.....	0·4	2·3	2·3	0·2	1·0	.....	**0·9**			
	2·7	1·8	−0·4	0·2	2·0	2·0	1·3	1·2	−1·6	0·4	0·2	**0·9**	.....	·008	
840	.....	.....	2·3	3·7	3·0	.....	.....	.....	.....	.....	.....	**2·7**			
	.....	.....	2·0	2·2	2·4	.....	.....	.....	.....	.....	.....	**2·1**	.....	·020	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
841	Boss 4814	R Lyrae	18 52·3	43 49	4·3	M7	·078	−13·0	.....	.....	.....
									−3·8	.....	.....
842	Boss 4815	Br. 2388	18 53·3	32 47	5·2	F9	·239	−23·8	5·3	5·7	3·8
									4·9	6·0	4·2
843	Boss 4817	.....	18 53·8	17 14	5·4	F8	·008	− 3·8	−2·1	−2·8	−3·2
									−3·0	−2·8	−3·8
844	Boss 4831	λ Lyrae	18 56·3	32 00	5·1	K4	·016	+ 4·5	.....	.....	.....
									.....	.....	.....
845	Boss 4833	.....	18 56·3	62 16	6·4	K0	·045	+ 8·1	1·6	1·2	.....
									0·7	2·7	.....
846	H.R. 7204	.....	18 57·3	33 40	6·2	K0	.....	.....	0·3	1·1	.....
									1·2	1·9	.....
847	Boss 4848	49 Draconis	18 58·8	55 31	5·5	G4	·015	+26·3	−0·7	0·2	1·5
									−1·1	0·3	0·6
848	Boss 4860	.....	19 01·1	31 36	5·8	K7	·088	+26·3	.....	.....	.....
									.....	.....	.....
849	Boss 4863	.....	19 02·2	76 55	6·5	F0	·079	−14·8	3·7	2·9	4·3
									3·4	3·6	2·6
850	H.R. 7252	.....	19 02·6	49 47	6·6	K5	.....	.....	.....	.....	.....
									.....	1·1	.....
851	H.R. 7260	.....	19 03·5	16 43	6·0	G5	.....	.....	4·3	5·8	4·3
									3·5	4·5	.....
852	H.R. 7263	.....	19 03·7	21 32	6·2	F3	.....	.....	3·7	3·0	1·3
									3·8	3·2	1·0
853	Boss 4875	.....	19 04·1	05 55	5·4	A7	·076	−36·3	1·5	3·0	1·6
									2·6	3·3	2·0
854	H.R. 7280	.....	19 07·4	26 34	6·3	F4	.....	.....	0·6	3·0	3·0
									.....	3·0	3·5
855	Boss 4893	.....	19 09·5	49 39	6·6	G5	·652	−22·7	4·0	5·2	.....
									5·2	5·5	.....
856	H.R. 7299	.....	19 10·7	20 02	6·1	K0	.....	.....	.....	0·3	.....
									.....	1·6	.....
857	H.R. 7302	.....	19 11·5	30 21	6·1	M0	.....	.....	.....	.....	.....
									.....	.....	.....
858	Boss 4907	54 Draconis	19 12·1	57 32	5·3	K2	·077	−11·8	2·5	2·1	.....
									4·0	1·2	.....
859	Boss 4909	δ Draconis	19 12·5	67 29	3·2	G8	·137	+40·6	1·0	0·3	.....
									0·7	1·5	.....
860	Boss 4911	59 Draconis	19 12·8	76 24	5·1	A9	·137	+ 8·2	2·9	1·1	3·5
									2·7	2·8	2·2
861	Boss 4912	θ Lyrae	19 12·9	37 57	4·5	K3	·007	−11·4	−2·1	.....	.....
									0·2	0·6	.....
862	Boss 4920	.....	19 14·0	46 49	6·0	F5	·284	−26·6	3·7	3·3	4·2
									3·4	4·1	3·7
863	Boss 4923	κ Cygni	19 14·8	53 11	4·0	G5	·135	−11·2	3·2	0·4	.....
									3·2	1·7	.....
864	Boss 4924	28 Aquilae	19 15·0	12 12	5·4	F0	·017	+17·5	1·1	0·7	3·0
									1·8	2·6	2·5

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π	
				−2·8		−1·2	−2·0	−2·3	−1·4	−2·4	−2·6	−2·1				
841	.....	.....	.....	−2·0	.....	−1·9	−2·7	−0·1	−1·1	−1·6	−1·2	−2·0	.....	·005	·028	
	.....	−2·7	−2·4									5·3				
842	2·7	.....	6·8	6·5	6·2	.....	.....	.....	.....	.....	.....	4·7	4·8	·091	·095	
	4·6	.....	4·2	3·6	5·1	.....	.....	.....	.....	.....	.....					
												−2·6				
843	.....	.....	−3·0	−2·3	−2·5	.....	.....	.....	.....	.....	.....	−2·4	0·3	·003	·001	
	.....	.....	−2·5	−0·4	−2·2	.....	.....	.....	.....	.....	.....					
							−0·1	−1·2	−1·6	−0·7	.....	−0·8				
844	0·8	−1·4	.....	−1·7	.....	.....	−1·4	−1·1	−1·4	−1·5	−0·5	−1·1	.....	·006		
	0·6	−1·0	−2·1	−1·2	.....	.....						1·3				
845	3·4	1·5	0·0	0·7	0·8	1·0	0·8	1·0	0·8	2·3	.....	0·7	.....	·008		
	1·2	1·0	1·0	−0·6	0·4	1·8	0·5	−0·5	−0·8	0·6	.....					
												0·6				
846	0·0	1·2	0·7	1·2	0·0	1·6	−0·6	1·0	0·2	0·5	.....	1·1	.....	·009		
	0·6	0·5	0·6	1·7	1·7	2·5	0·0	.....	.....	0·6	.....					
												0·2				
847	0·0	−0·3	0·6	1·3	−0·9	.....	.....	.....	.....	.....	.....	0·4	.....	·009		
	1·2	0·8	1·6	−1·5	0·4	1·1	.....	.....	.....	.....	.....					
							−2·0	−1·5	−0·2	−0·9	.....	−1·1:				
848	.....	.....	.....	.....	.....	.....	−1·2	−0·3	−1·3	−1·0	−1·2	−0·9:	0·7	·004		
	0·3	−1·5	.....	.....	.....	.....						3·0				
849	2·8	2·0	2·5	.....	.....	.....	.....	.....	.....	.....	.....	3·0	.....	·020		
	2·9	2·4	3·0	.....	.....	.....	.....	.....	.....	.....	.....					
								1·2	−0·8	−0·9	0·4	−0·2:				
850	.....	.....	.....	−0·8	.....	.....	.....	0·2	−0·4	0·3	−0·3	−0·2:	.....	·004		
	.....	−0·4	−2·2:	−1·1	.....	.....						4·1				
851	6·0	.....	2·4	2·7	3·0	.....	.....	.....	.....	.....	.....	3·7	.....	·038		
	5·4	3·7	3·3	1·7	2·4	4·7	.....	.....	.....	.....	.....					
												3·1				
852	.....	.....	3·4	3·7	3·7	.....	.....	.....	.....	.....	.....	2·8	.....	·022		
	.....	.....	2·0	2·9	4·0	.....	.....	.....	.....	.....	.....					
												2·1				
853	.....	.....	1·8	.....	.....	2·5	.....	.....	.....	.....	.....	2·5	.....	·024		
	.....	.....	2·8	2·2		2·1	.....	.....	.....	.....	.....					
												2·6				
854	.....	.....	4·8	.....	.....	1·5	.....	.....	.....	.....	.....	3·0	.....	·020		
	.....	.....	3·2	3·9		1·2	.....	.....	.....	.....	.....					
												4·7				
855	6·3	.....	2·4	5·8	.....	4·5	.....	.....	.....	.....	.....	4·7	5·7	·042	·045	
	6·2	5·0	4·9	3·0	.....		3·0	.....	.....	.....	.....					
								0·1	1·7	−1·6	−1·4	0·3				
856	2·2	1·8	−1·4	0·2	.....	.....	1·4	.....	.....		−1·2	0·5	.....	·007		
	1·0	1·9	−0·2	−1·2	.....	.....										
							−0·2	0·6	0·5	−1·0	−1·5	−0·2	−0·3			
857	.....	.....	.....	−0·4	.....	.....	.....	1·2	1·1	−1·1	−0·9	−0·3	−0·2	·005		
	−1·3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....					
												2·2				
858	2·9	1·0	3·0	1·4	1·3	2·0	2·3	3·2	3·0	1·1	2·6	1·3	1·8	·022		
	1·4	0·8	0·6	0·2	2·0											
							0·8	0·9	0·3	−0·6	1·5					
859	0·7	1·0	1·1	1·7	1·0	0·8	1·4	−0·3	0·6	0·8	1·4	.....	0·8	0·036	·035	
	2·1	1·8	1·3	2·3	0·2								1·2			
												2·5				
860	.....	.....	2·5	.....	2·6	.....	.....	.....	.....	.....	.....	2·3	.....	·029		
	.....	.....	2·2	2·0	2·1	.....	.....	.....	.....	.....	.....					
												−1·2				
861	0·8	−1·4	−3·1	−2·0	0·8	−1·0	−0·7	−1·4	−3·1	0·2	.....	−0·9	0·2	·008		
	−2·3	−1·9	−2·4	−2·0	1·5	1·1	1·5	−3·8	−3·0	−0·8	−0·7					
												3·3				
862	.....	.....	2·7	3·6	2·6	.....	.....	.....	.....	.....	.....	3·7	2·8	·032	·018	
	.....	.....	3·4	4·1	3·2	.....	.....	.....	.....	.....	.....					
												2·3				
863	1·0	1·6	4·6	1·6	3·4	.....	.....	.....	.....	.....	.....	1·8	1·1	·041	·040	
	1·3	−0·4	4·4	3·4	1·9	1·8	0·0	0·6	.....	.....	.....					
												1·4				
864	.....	.....	1·4	.....	0·8	.....	.....	.....	.....	.....	.....	1·8	.....	·017		
	.....	.....	1·4	1·3	1·1	.....	.....	.....	.....	.....	.....					

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
865	Boss 4950	31 Aquilae	19 20·2	11 44	5·2	G6	·963	−79·6	4·6 4·2	3·1 3·3	....
866	Boss 4958	.....	19 20·8	43 12	6·0	G5	·049	− 6·4	0·3 −1·6	2·2 1·5	....
867	Boss 4961	.....	19 21·3	24 44	6·2	F6	·656	+13·9	4·1 4·1	2·7 2·3	5·3 5·4
868	Boss 4971	.....	19 22·5	88 59	6·6	M4	·028	+10·8	....	....	....
869	Boss 4976	α Vulpeculae	19 24·5	24 28	4·6	M0	·168	−67·0	0·8 0·1	....	....
870	Boss 4977	.....	19 24·8	14 23	5·7	K1	·053	−22·5	−1·5	0·0 1·6	..... 1·8
871	Boss 4986	β^1Cygni	19 26·7	27 45	3·2	K0	·010	− 4·1	−0·3 −1·6	....	....
872	Boss 4994	.....	19 28·7	50 06	5·7	K2	·045	+ 8·6	−0·5 1·1	−0·9 1·4	....
873	Boss 4995	μ Aquilae	19 29·2	07 10	4·6	K4	·265	− 6·7	2·6 4·3	....	....
874	.....	Lal. 37120	19 29·7	32 59	6·6	G1	·517	−143·2	5·9 5·1	5·0 5·0	5·6 4·8
875	Boss 5000	.....	19 30·9	29 14	5·4	F4	·026	+ 6·7	3·7 4·2	0·0 0·0	4·4 5·1
876	Boss 5009	σ Draconis	19 32·6	69 29	4·8	G9	1·842	+41·1	5·4 5·9	6·5 6·1	....
877	Boss 5010	.....	19 32·8	16 14	5·7	G8	·022	−14·3	0·3 −1·1	0·3	....
878	Boss 5014	θ Cygni	19 33·8	49 59	4·6	F3	·247	−10·5	3·0 3·4	2·8 2·8	4·3 3·4
879	Boss 5021	φ Cygni	19 35·5	29 56	4·8	K0	·034	+22·8	..... 0·4:	1·8	....
880	Boss 5023	α Sagittae	19 35·6	17 47	4·4	F7	·038	+20·4	0·5 0·2	0·2 −1·2	1·8 1·6
881	Boss 5026	.....	19 36·4	54 44	6·6†	F5	·176	+ 1·5	5·3 3·8	3·1 3·0	4·4 3·6
882	H.R. 7487	.....	19 36·6	45 43	6·3	G8	.....	.....	−0·9 0·0	0·9 1·4	....
883	Boss 5027	β Sagittae	19 36·6	17 15	4·4	G7	·039	− 3·8	−0·7 0·0	−0·8 0·9	....
884	Boss 5031	Groom. 2909	19 37·7	45 17	5·0	F5	·144	− 2·5	1·1 1·6	3·6 2·8	−1·3 −1·3
885	Boss 5037	16^1 Cygni	19 39·1	50 18	6·3	G2	·216	− 8·4	4·3 5·7	4·9 4·6	5·6 5·1
886	Boss 5038	16^2 Cygni	19 39·2	50 17	6·4	G3	·203	−11·4	5·0 5·6	4·9 4·1	2·8 3·5
887	Boss 5045	15 Cygni	19 40·7	37 07	5·0	G6	·079	− 5·4	1·5 1·4	0·7 0·1	....
888	Boss 5047	γ Aquilae	19 41·5	10 22	2·8	K3	·018	+15·1	0·0 0·2	....	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
865	5·4	4·0	2·4	3·0	6·6	.....	.....	.....	.....	.....	.....	4·2			
	4·7	3·9	4·2	5·0	6·0:	4·6	6·2	7·0	.....	.....	.....	4·9	5·1	·074	·067
866	1·0	0·4	1·8	−0·7	0·2	1·1	.....	−0·3	−1·0	1·3	.....	0·6			
	1·9	1·3	2·4	0·2	0·8	1·8	.....	.....	0·4	1·5	.....	1·0	.....	·009	
867	.....	.....	1·7	3·8	3·0	.....	.....	.....	.....	.....	.....	3·4			
	3·6	.....	4·4	4·3	4·4	.....	.....	.....	.....	.....	.....	4·1	3·9	·032	·042
868	.....	.....	.....	.....	.....	.....	−1·5	−1·0	−1·3	−0·9	−1·6	−1·3:			
	.....	−0·1	.....	.....	.....	.....	−2·8	−2·7	−0·9	−0·4	−0·2	−1·2:	.....	·003	
869	.....	.....	.....	0·5	.....	−0·1	1·0	−0·7	−0·7	−1·1	−0·2	−0·1			
	.....	−1·3	0·0	2·0	.....	−0·2	1·0	−1·5	−0·9	−1·1	−0·8	−0·3	0·1	·011	
870	0·0	1·4	0·0	0·9	−0·5	0·7	−0·6	0·3	−0·5	1·4	.....	0·1			
	1·2	1·7	−0·2	1·7	1·5	2·3	1·4	0·6	−0·8	1·6	.....	1·2	.....	·010	
871	−0·7	0·0	1·4	−1·6	0·8	−0·9	−2·3	−1·4	0·8	1·4	.....	−0·1			
	−1·4	0·0	0·1	−0·2	0·2	−0·2	−1·8	−0·7	−0·2	0·0	−0·8	−0·5	0·8	·020	·000
872	0·0	.....	−0·4	−1·0	−1·3	−1·6	−1·1	1·2	−0·3	0·2	.....	−0·3			
	0·6	1·1	−0·5	−1·5	−2·3	2·0	1·8	1·3	−1·5	0·7	0·0	0·3	.....	·007	
873	3·1	1·6	.....	−0·3	.....	−0·4	1·5	3·5	2·0	3·1	.....	1·8			
	2·0	1·4	0·6	0·1	1·2	−0·8	2·2	2·0	2·0	2·0	0·8	1·5	0·7	·026	·021
874	4·7	.....	3·4	5·9	3·8	.....	.....	.....	.....	.....	.....	4·9			
	5·0	.....	2·6	3·5	2·6	.....	.....	.....	.....	.....	.....	4·1	4·4	·038	·043
875	.....	.....	3·7	1·5	3·1	.....	.....	.....	.....	.....	.....	2·7			
	.....	.....	1·8	0·6	3·2	.....	.....	.....	.....	.....	.....	2·5:	.....	·028	
876	6·1	6·3	4·7	3·6	4·8	.....	.....	.....	6·6	6·5	.....	5·6			
	5·2	6·8	5·4	6·8	4·3	5·4	4·7	6·8	5·4	.....	.....	5·8	5·8	·151	·192
877	1·2	0·4	−0·5	0·2	0·8	1·4	−1·4	−0·3	0·0	1·5	.....	0·3			
	0·9	0·2	1·2	−0·2	−1·2:	−2·0:	.....	.....	0·0	1·2	.....	0·3	.....	·008	
878	.....	.....	3·0	4·3	3·6	.....	.....	.....	.....	.....	.....	3·5			
	.....	.....	2·8	3·4	3·0	.....	.....	.....	.....	.....	.....	3·1	3·4	·056	·070
879	0·8	0·0	0·5	−1·6	−0·7	0·2	−2·0	0·2	0·2	1·7	.....	0·1			
	.....	0·1	−0·8	−1·5	0·8	1·8	0·8	0·3	0·6	2·8	0·2	0·4	0·9	·012	
880	.....	.....	−1·6	0·0	1·2	.....	.....	.....	.....	.....	.....	0·3			
	.....	.....	−1·3	−0·6	3·5:	.....	.....	.....	.....	.....	.....	0·1	−0·9	·014	−·004
881	.....	.....	5·0	5·1	3·5	.....	.....	.....	.....	.....	.....	4·4			
	.....	.....	3·7	4·1	3·8	.....	.....	.....	.....	.....	.....	3·7	.....	·031	
882	−0·1	0·5	0·0	3·0	−0·7	0·7	2·3	1·6	−0·3	1·3	.....	0·7			
	1·5	0·1	1·2	2·0	2·6	1·5	0·4	.....	.....	2·7	.....	1·3	.....	·009	
883	−1·4	0·0	0·1	2·2	0·2	1·1	−0·1	0·9	0·8	2·2	.....	0·4			
	−0·2	0·1	2·0	2·9	3·2	1·8	0·9	−0·4	.....	1·8	.....	1·2	0·0	·019	
884	.....	.....	1·3	1·5	1·1	.....	.....	.....	.....	.....	.....	1·2			
	.....	.....	0·0	3·2	1·4	.....	.....	.....	.....	.....	.....	1·3	1·5	·018	−·003
885	4·3	.....	5·5	5·1	6·0	.....	.....	.....	.....	.....	.....	5·1			
	2·4	3·2	4·8	4·4	5·5	.....	.....	.....	.....	.....	.....	4·5	5·1	·050	·038
886	5·6	.....	5·3	5·6	3·8	.....	.....	.....	.....	.....	.....	4·7			
	4·2	4·6	6·0	4·7	2·4	.....	.....	.....	.....	.....	.....	4·4	4·6	·043	·038
887	2·0	0·8	0·9	0·5	0·2	1·3	1·0	0·5	−0·3	1·0	.....	0·8			
	1·6	1·2	0·6	1·5	1·4	−0·2	1·0	1·0	.....	.....	.....	1·0	0·1	·015	·020
888	−0·7	−1·4	1·3	−0·8	.....	0·0	−0·3	−1·7	−2·7	−2·1	.....	−0·8			
	−0·3	−0·2	1·0	0·5	−1·3	0·8	−0·6	0·0	−0·7	−1·4	−0·3	−0·2	0·3	·022	·034

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
889	Boss 5049	.....	19 42·1	34 46	6·2	G8	·014	− 0·6	0·3 1·2	0·9 2·1	....
890	Boss 5051	17 Cygni br.	19 42·6	33 30	5·0	F6	·453	+24·0	2·6 3·3	3·2 3·4	4·3 3·4
891*	Boss 5052	δ Sagittae	19 42·9	18 17	4·3†	G+M	·009	+21·0	−0·2 −0·5	....	....
892	Boss 5065	*o* Aquilae	19 46·2	10 10	5·2	G0	·278	+14·1	3·7 3·7	3·4 3·7	4·9 4·0
893	Boss 5071	η Aquilae	19 47·4	00 45	4·1	F6	·015	+ 1·4	−2·4 −3·2	..... −1·7	−3·0 −2·2
894	Boss 5075	20 Cygni	19 48·1	52 44	5·2	K4	·072	− 3·0	1·5 2·7	....	....
895	H.R. 7577	.....	19 48·3	47 09	6·2	F0*n*	.....	.....	−0·2 1·4	1·4 3·3	2·4 1·4
896	Boss 5089	ξ Aquilae	19 49·4	08 12	4·9	G8	·129	−25·0	2·2 2·5	0·6 1·2	....
897	Boss 5093	β Aquilae	19 50·4	06 09	3·9	G7	·486	−23·1	4·3 4·8	3·4 3·0	....
898	Boss 5098	S Sagittae	19 51·5	16 22	5·8	G1	·008	+ 8·9	−2·8 −3·0	−3·9 −3·2	−6·0: −4·0
899	Boss 5103	η Cygni	19 52·6	34 49	4·0	G9	·051	− 7·8	1·9 3·7	1·8 1·4	....
900	Boss 5118	γ Sagittae	19 54·3	19 13	3·7	K8	·065	−16·1	−0·5 1·4	..... 0·5	....
901	Boss 5137	26 Cygni	19 58·5	49 49	5·3	K0	·022	+17·6	−0·6 0·1	0·5 1·4	....
902	Boss 5144	.....	19 59·5	29 38	5·7	G7	·858	−28·4	6·7 5·2	4·6 3·9	....
903	Boss 5146	15 Sagittae	19 59·7	16 48	5·9	G3	·576	+20·4	2·7 4·0	5·3 5·0	4·7 3·9
904	Boss 5151	.....	20 00·7	19 42	5·3	K2	·083	−23·2	2·2 1·6	1·7 1·5	....
905	Boss 5154	.....	20 02·4	76 13	6·4	M2	·059	−56·7	....	....	....
906	Boss 5157	27 Cygni	20 02·7	35 42	5·5	G8	·494	−14·1	4·7 3·1	3·8 3·7	....
907	H.R. 7693	.....	20 03·1	09 06	6·4	F2	.....	.....	3·3 2·8	2·5 2·7	5·0 4·6
908	Boss 5163	.....	20 03·6	52 51	5·7	F5	·335	−24·1	2·9 3·4	4·3 4·4	3·8 3·7
909	Boss 5184	68 Draconis	20 09·9	61 47	5·7	F7	·158	− 1·3	0·3 0·1	0·1 0·5	4·1 3·0
910	Boss 5187	R31 Cygni	20 10·5	46 26	4·0	G9	·006	+14·2	−0·2 0·3	....	....
911	Boss 5192	22 Vulpeculae	20 11·2	23 12	5·4	G7	·015	+ 9·3	−4·0 −4·2	−2·0 −1·0	....
912*	Boss 5200	32 Cygni	20 12·3	47 24	4·7†	K7	·008	+ 2·8	−2·0 0·6	....	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
889	2·0	1·0	0·2	2·0	0·0	0·2	0·2	−0·2	−0·2	2·2	.....	0·7			
	0·6	0·2	0·8	0·3	0·5	0·3	0·4	−0·4	1·0	3·2	.....	0·9	.....	·008	
890	.....	.....	2·4	4·8	2·7	.....	.....	.....	.....	.....	.....	3·3			
	3·0:	.....	0·9	2·5	3·4	.....	.....	.....	.....	.....	.....	2·9	2·9	·042	·045
891	.....	.....	.....	−0·8	.....	0·2	−0·3	−0·7	−2·2	−2·4	−2·0	−1·0:			
	.....	−1·9	−3·1	−0·7	.....	−0·8	−0·1	−1·2	−1·8	−1·5	−1·4	−1·3:	0·2	·008	
892	4·9	.....	3·0	4·5	3·6	.....	.....	.....	.....	.....	.....	4·0			
	4·6	.....	2·0	2·7	2·5	.....	.....	.....	.....	.....	.....	3·3	.....	·049	
893	.....	.....	−1·4	−1·9	−2·3	.....	.....	.....	.....	.....	.....	−2·2			
	.....	.....	−1·4	−1·8	−2·4	.....	.....	.....	.....	.....	.....	−2·1	−2·7	·006	·004
894	1·0	0·0	.....	0·5	.....	2·5	2·5	2·3	3·7	3·7	.....	2·0			
	1·6	−0·8	0·6	1·2	1·6	0·6	0·4	0·3	2·3	2·9	2·3	1·3	.....	·019	·020
895	.....	.....	2·3	.....	2·3	.....	.....	.....	.....	.....	.....	1·6			
	.....	.....	2·2	2·2	3·0	.....	.....	.....	.....	.....	.....	2·2	.....	·014	
896	3·8	3·0	0·7	.....	0·0	2·8	0·2	1·2	0·8	−0·8	.....	1·3			
	0·4	2·0	1·2	−0·6	0·4	0·3	0·9	0·6	.....	.....	.....	0·9	.....	·017	·039
897	4·8	4·9	2·5	2·2	2·8	.....	.....	.....	.....	.....	.....	3·5			
	4·0	.....	1·9	3·2	1·3	6·0	2·0	3·8	.....	.....	.....	3·3	3·9	·080	·076
898	.....	.....	−3·7	+3·6	−3·7	.....	.....	.....	.....	.....	.....	−3·9			
	−1·8	.....	−3·3	1·9	+3·1	−3·0	2·4	2·8	.....	.....	.....	−2·8	−2·5	·001	·004
899	3·8	3·0	2·5	4·0	1·0	1·0	.....	.....	.....	.....	.....	2·4			
	3·7	2·9	3·2	3·3	2·6	3·0	.....	.....	.....	.....	.....	3·0	1·8	·056	
900	1·8	0·3	.....	1·6	.....	1·0	3·1	0·8	0·0	−0·5	.....	0·8			
	0·0	−1·5	0·9	3·4	1·0	0·7	0·8	0·3	−0·3	0·7	0·3	0·6	0·5	·025	·005
901	1·7	0·0	0·4	−0·4	−0·7	0·9	1·9	0·4	0·4	0·5	.....	0·3			
	1·5	0·1	−0·2	−0·2	1·6	2·0	0·5	1·3	0·0	2·2	.....	0·9	.....	·012	
902	5·0	3·1	5·0	5·2	5·6	.....	.....	.....	.....	.....	.....	5·0			
	3·9	4·3	3·1	4·7	5·9	4·9	.....	4·6	.....	.....	.....	4·5	4·8	·064	·049
903	5·9	.....	4·2	5·6	4·2	.....	.....	.....	.....	.....	.....	4·6			
	5·1	5·0	4·1	3·6	3·4	.....	.....	.....	.....	.....	.....	4·3	5·0	·052	·104
904	4·6	2·5	2·1	3·1	2·8	2·2	.....	.....	.....	.....	.....	2·6			
	1·8	1·8	0·6	1·1	1·7	1·8	2·4	3·0	2·3	2·6	.....	1·8	.....	·024	
905	.....	.....	.....	.....	.....	.....	−2·6	−2·0	0·1	0·3	−0·3	−0·9:			
	.....	−0·1	.....	.....	.....	.....	−2·8	−1·4	−0·7	−0·2	−0·2	−0·9:	.....	·004	
906	4·2	3·4	3·1	6·4	5·6	.....	.....	.....	.....	.....	.....	4·4			
	3·0	3·7	3·7	4·8	.....	4·4	4·5	5·3	.....	.....	.....	4·0	4·1	·056	·051
907	.....	.....	1·0	.....	3·3	.....	.....	.....	.....	.....	.....	3·0:			
	.....	.....	−0·3	2·4	3·1	.....	.....	.....	.....	.....	.....	2·6:	.....	·019	
908	.....	.....	3·3	3·6	3·0	.....	.....	.....	.....	.....	.....	3·5			
	.....	.....	3·4	3·1	3·8	.....	.....	.....	.....	.....	.....	3·6	3·9	·037	·056
909	4·1	.....	3·9	1·6	2·8	.....	.....	.....	.....	.....	.....	2·4			
	4·1	.....	2·1	0·8	2·5	.....	.....	.....	.....	.....	.....	1·9	3·0	·019	·037
910	−0·7	0·0	0·9	−0·5	0·0	−1·3	−3·5	−2·0	−2·2	−1·0	.....	−1·0			
	0·4	0·0	1·0	0·0	−1·7	−2·9	0·0	−2·4	−1·2	−0·4	−1·1	−0·7	−2·0	·011	−·002
911	.....	−1·9	−4·0	−2·2	−1·4	−0·1	0·5	−2·0	−2·9	−1·1	.....	−1·9			
	−2·8	−0·9	−3·0	−3·0	−0·6	0·0	0·5	−1·6	.....	−1·1	.....	−1·6	.....	·004	
912	−0·2	0·5	.....	−0·6	.....	−1·0	−0·7	−0·8	−0·9	−1·5	.....	−0·8			
	−1·0	−1·9	−2·6	−1·6	0·0	0·3	0·2	0·3	−1·3	0·0	−0·4	−0·6	.....	·008	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
913	Boss 5201	24 Vulpeculae	20 12·5	24 22	5·4	G7	·030	+29·5	−0·5 0·0	0·8 1·5	....
914	Boss 5202	α^2 Capricorni	20 12·5	−12 51	3·8	G7	·062	+11·9	....	3·6 4·3	....
915	Boss 5203	.....	20 12·8	45 16	5·9	F4	·060	−24·2	2·7 3·0	3·1 3·2	4·0 3·9
916	Boss 5204	.....	20 13·0	64 27	7·2	G5	·050	−52·4	4·0 2·7	2·7 3·2	....
917	Boss 5205	.....	20 13·4	40 03	5·5	K5	·014	− 3·9	....	....	....
918	Boss 5213	35 Cygni	20 14·8	34 40	5·2	F7	·020	+ 3·5	−2·9 −2·0	−4·7 −2·9	−2·1 −2·0
919	Boss 5219	.....	20 16·4	66 31	6·1	G2	·558	+10·3	4·7 5·7	4·9 5·7	5·1 4·5
920	H.R. 7793	.....	20 18·2	14 13	6·2	F3	.....	.....	3·4 4·2	5·4 5·3	6·0 4·8
921	Boss 5226	.....	20 18·2	05 01	5·4	G9	·053	+ 2·7	0·9 0·9	0·0 1·6	....
922	H.R. 7795	.....	20 18·5	40 48	6·4	G7	.....	.....	−1·1 −2·4	..... −2·6	....
923	Boss 5229	γ Cygni	20 18·6	39 56	2·3	F7	·006	+11·7	−3·4 −3·6	..... −2·4	−3·1 −2·3
924	H.R. 7797	.....	20 18·6	30 56	6·2	K6	.....	.....	....	....	....
925	Boss 5230	.....	20 18·9	45 27	5·9	K0	·048	− 5·9	0·5 0·8	1·2 2·6	....
926	Boss 5235	39 Cygni	20 19·9	31 52	4·6	K5	·044	+ 4·4	−0·5 0·1	....	....
927	Boss 5255	41 Cygni	20 25·3	30 02	4·1	F5	·014	− 2·1	−0·8 −0·2	....	−1·6 −1·0
928	Boss 5271	.....	20 28·2	48 53	5·6	M1	·041	−49·4	....	....	....
929	.....	Groom 3215	20 29·3	41 32	7·0	K0	·475	+ 5·8	5·2 2·6	5·8 5·9	....
930	Boss 5280	.....	20 30·4	72 12	6·4	K5	·026	−29·3	....	....	....
931	Boss 5291	β Delphini	20 32·9	14 15	4·0†	F3	·118	− 9·4	0·8 1·6	0·4 1·7	2·4 1·6
932	Boss 5294	71 Aquilae	20 33·2	−01 27	4·5	G8	·030	+ 6·3	−0·9 1·2	0·3 1·1	....
933	Boss 5299	.....	20 34·1	12 58	6·1	K5	·021	+ 0·3	....	....	....
934	Boss 5308	75 Draconis	20 34·5	81 05	5·6	G8	·033	.....	−0·9 0·0	0·6 1·7	....
935	Boss 5309	.....	20 34·9	29 59	5·9	G9	·090	+29·1	1·5 0·6	1·0 2·1	....
936	Boss 5321	.....	20 38·2	60 09	6·0	F6	·184	+ 3·7	3·1 3·6	3·8 3·5	3·9 3·2

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
913	2·6	0·9	0·6	−0·1	−0·8	0·3	0·5	0·6	0·2	0·7	.....	**0·5**			
	1·8	0·7	1·1	0·8	0·6	0·6	0·1	−0·2	0·2	1·2	.....	**0·7**	0·5	·011	−·027
914	0·6	1·0	1·2	0·3	.....	.....	−1·1	1·8	0·2	1·7	.....	**1·0**			
	2·7	2·6	2·4	−0·6	0·5	0·3	2·0	2·5	2·1	2·7	.....	**1·9**	1·2	·034	
915	.....	.....	4·0	3·6	3·2	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	2·4	2·1	3·4	.....	.....	.....	.....	.....	.....	**3·0**	.....	·029	
916	6·0	3·0	1·3	2·7	1·9	.....	.....	.....	.....	.....	.....	**3·1**:			
	6·4	3·7	0·9	−0·4	.....	.....	.....	.....	.....	.....	.....	**2·8**:	.....	·014	
917	.....	0·0	.....	−1·1	.....	.....	−1·4	−2·4	−2·4	−1·3	.....	**−1·4**:			
	−0·6	−1·7	−2·3	−1·2	.....	.....	−1·7	−1·7	−1·6	−1·0	−1·0	**−1·4**	.....	·004	
918	.....	.....	−2·0	−0·9	−3·4	.....	.....	.....	.....	.....	.....	**−2·7**			
	−2·6	.....	−1·3	−3·6	−2·6	.....	.....	.....	.....	.....	.....	**−2·7**	.....	·003	
919	5·5	.....	4·7	5·6	4·6	.....	.....	.....	.....	.....	.....	**5·0**			
	4·7	4·6	4·0	2·7	4·5	.....	.....	.....	.....	.....	.....	**4·6**	5·2	·056	·120
920	.....	.....	5·2	4·6	3·4	.....	.....	.....	.....	.....	.....	**4·7**			
	.....	.....	3·4	3·6	3·6	.....	.....	.....	.....	.....	.....	**4·2**	.....	·044	
921	3·0	3·0	−0·4	1·4	1·2	0·8	0·2	2·8	2·3	2·0	.....	**1·4**			
	2·2	2·4	−1·4	−0·9	2·1	1·5	2·9	2·8	0·9	1·1	.....	**1·3**	.....	·016	
922	1·6	.....	−1·7	1·3	0·9	−0·7	0·8	−1·6	−2·0	−0·1	.....	**−0·3**			
	−1·2	0·2	−0·6	1·2	1·3	−0·9	−0·2	−0·3	.....	.....	.....	**−0·6**	.....	·004	
923	.....	.....	−2·6	−3·0	−4·4	.....	.....	.....	.....	.....	.....	**−3·3**			
	.....	.....	−3·7	−3·6	−2·8	.....	.....	.....	.....	.....	.....	**−3·1**	−3·0	·008	·014
924	1·3	.....	.....	0·3	.....	.....	1·0	0·2	−0·3	0·4	.....	**0·5**:			
	1·3	0·6	.....	.....	.....	.....	0·9	−0·2	.....	0·2	−0·6	**0·4**:	.....	·007	
925	2·8	1·8	1·0	1·0	0·0	1·4	3·0	2·1	0·2	2·1	.....	**1·4**			
	1·9	1·0	2·5	1·1	1·7	2·0	2·7	1·7	0·0	3·0	.....	**1·8**	.....	·014	
926	1·0	.....	.....	0·6	.....	0·2	1·7	1·7	−0·9	−0·2	.....	**0·4**			
	1·2	1·0	−0·8	−0·4	0·1	1·1	0·3	.....	.....	−0·4	0·2	**0·2**	0·5	·014	
927	.....	.....	0·5	−1·0	−1·6	.....	.....	.....	.....	.....	.....	**−0·9**			
	.....	.....	0·2	−0·5	−2·0	.....	.....	.....	.....	.....	.....	**−0·7**	−1·1	·010	−·018
928	.....	.....	.....	−1·8	.....	−1·5	−2·3	−1·2	1·3	0·3	−0·2	**−0·8**			
	.....	0·0	−2·4	−1·0	.....	−3·1	−1·3	0·0	−0·9	−0·4	−0·7	**−1·1**	.....	·005	
929	7·5	7·0	3·2	4·5	5·1	.....	.....	.....	5·7	6·6	.....	**5·6**			
	6·9	6·6	2·5	2·7	6·8	6·9	5·5	6·0	7·6	6·4	.....	**5·4**	6·0	·050	·036
930	1·5	−0·2	.....	−0·7	.....	.....	−0·4	0·2	−0·4	0·8	.....	**0·1**			
	0·2	1·0	−1·4	0·3	.....	0·3	1·3	0·0	−0·2	0·4	.....	**0·2**	0·8	·006	
931	.....	.....	0·5	2·8	2·6	.....	.....	.....	.....	.....	.....	**1·6**			
	.....	.....	2·1	4·0	2·1	.....	.....	.....	.....	.....	.....	**2·2**	2·3	·038	·027
932	2·2	2·8	−1·6	1·8	0·2	0·2	0·2	0·3	−1·2	1·3	.....	**0·5**			
	1·6	0·3	0·6	0·3	1·8	1·5	1·1	0·5	−0·3	−0·1	.....	**0·8**	.....	·017	
933	0·8	−0·5	.....	−1·7	.....	0·9	−0·2	−2·3	−2·2	−1·3	.....	**−0·8**			
	−1·8	−1·6	−2·1	−2·6	0·4:	0·9	0·6	−0·5	−1·6	−0·5	−0·4	**−0·8**	.....	·004	
934	0·9	1·0	0·7	0·2	2·3	0·7	0·6	−1·3	−0·3	2·1	.....	**0·6**			
	2·4	1·4	1·2	0·3	1·2	0·3	−0·3	−0·4	.....	.....	.....	**0·8**	.....	·010	
935	1·6	1·2	0·2	−0·7	0·8	0·4	0·6	0·0	0·2	0·7	.....	**0·6**			
	1·6	1·4	−0·3	−1·0	2·1:	0·7	0·5	0·9	0·2	1·1	.....	**0·8**	.....	·009	
936	.....	.....	2·9	3·2	3·6	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	2·9	4·0	2·6	.....	.....	.....	.....	.....	.....	**3·3**	3·6	·030	·049

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
937	.....	*X* Cygni	20 39·5	35 14	6·5	G4	·020	+25·9	−6·0:	−2·7	−4·0
									−3·2	−1·8	−4·0
938	Boss 5331	52 Cygni	20 41·6	30 21	4·3	G9	·025	+15·3	1·2	0·7	.....
									2·2	1·4	.....
939	Boss 5334	γ^1 Delphini ft.	20 42·0	15 46	5·5	F8	·197	+ 5·3	1·7	2·4	2·3
									1·6	2·4	2·7
940	Boss 5335	γ^2 Delphini br.	20 42·0	15 46	4·5	K1	·207	+ 9·1	2·1	1·9	.....
									2·6	2·1	.....
941	Boss 5336	ϵ Cygni	20 42·2	33 36	2·6	G7	·485	+ 6·5	2·7	0·0	.....
									3·8	0·6	.....
942	Boss 5344	.....	20 42·9	57 13	4·6	F7	·243	−15·7	4·7	3·7	4·2
									4·2	3·2	4·5
943	Boss 5346	η Cephei	20 43·3	61 27	3·6	G6	·824	−72·0	4·3	3·0	.....
									5·0	2·5	.....
944	Boss 5355	.....	20 44·6	47 28	5·6	K4	·029	−13·3	.....	.....	.....
									.....	.....	.....
945	H.R. 7972	.....	20 44·9	52 03	6·3	K0	.....	.....	4·0	4·1	.....
									3·4	3·4	.....
946	Boss 5358	15 Delphini	20 44·9	12 11	6·0	F3	·114	+16·4	3·6	3·6	5·1
									3·6	3·2	4·6
947	Boss 5365	56 Cygni	20 46·6	43 41	5·1	A6	·180	− 8·5	0·9	1·8	1·5
									1·0	3·0	−0·1
948	Boss 5370	T Vulpeculae	20 47·2	27 52	5·8	F7	·018	+14·6	−2·5	−3·9	−3·3
									−1·0	−1·3	−2·4
949	Boss 5373	31 Vulpeculae	20 47·8	26 43	4·8	G5	·102	+17·5	−0·2	−1·0	3·5
									−1·1	−0·4	.....
950	Boss 5385	17 Delphini	20 50·9	13 21	5·4	G9	·027	+ 5·0	1·2	0·6	.....
									1·8	1·6	.....
951	Boss 5388	.....	20 52·1	80 11	5·6	K2	·040	−14·5	0·5	0·0	.....
									1·4	0·6	.....
952	Boss 5401	.....	20 54·8	44 04	5·8	K0	·128	−15·9	0·7	1·6	.....
									1·9	2·4	.....
953	Boss 5412	.....	20 57·0	59 02	5·8	K5	·051	+ 0·7	−1·9	.....	.....
									.....	.....	.....
954	Boss 5416	.....	20 58·5	39 06	6·5	K2	·008	+ 5·9	.....	.....	.....
									.....	.....	.....
955	Boss 5425	.....	21 00·1	41 14	6·3	F2*n*	·053	+ 4·3	−0·1	2·0	−0·2
									0·4	2·3	0·4
956	H.R. 8072	.....	21 00·2	49 57	6·4	K0	.....	.....	1·9	1·8	.....
									−0·4	1·8	.....
957	Boss 5428	4 Equulei	21 00·5	05 34	6·0	F7	·169	−10·4	2·6	2·6	3·9
									3·4	3·2	3·7
958	H.R. 8078	.....	21 00·7	52 53	6·1	K0	.....	.....	1·6	.....	.....
									2·6	1·8	.....
959	Boss 5431	ξ Cygni	21 01·3	43 32	3·9	K4	·011	− 3·3	−2·4	.....	.....
									−1·1	.....	.....
960	H.R. 8082	.....	21 02·1	26 32	6·2	K1	.....	.....	3·9	.....	.....
									2·4	1·8	.....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
937	.....	.....	−4·5	−3·0	−3·5	.....	.....	.....	.....	.....	.....	−3·9			
	−3·4	.....	−3·2	−3·4	−2·6	.....	.....	.....	.....	.....	.....	−3·1	−2·1	·001	·006
938	0·5	2·3	2·6	1·1	2·2	0·8	1·3	2·3	0·8	1·7	.....	1·4			
	.....	1·7	3·7	2·9	2·4	0·1	0·5	1·3	.....	2·4	.....	1·9	.....	·030	·014
939	.....	.....	2·9	4·1	3·6	.....	.....	.....	.....	.....	.....	2·8			
	3·8	.....	4·2	4·0	4·0	.....	.....	.....	.....	.....	.....	3·2	3·0	·032	·026
940	1·2	2·3	3·0	2·9	1·7	3·0	3·3	2·8	4·0	3·0	.....	2·6			
	2·0	3·5	.....	3·5	2·0	3·0	4·8	4·4	2·4	2·6	2·0	2·9	1·1	·044	·026
941	1·1	0·0	3·0	2·2	1·3	.....	.....	.....	.....	.....	.....	1·4			
	1·4	−0·2	1·9	1·8	1·7	0·6	0·6	2·1	.....	.....	.....	1·4	0·8	·058	·036
942	1·1	.....	3·6	4·6	4·5	.....	.....	.....	.....	.....	.....	3·8			
	3·3	.....	3·3	1·9	4·2	.....	.....	.....	.....	.....	.....	3·5	3·5	·064	·032
943	4·6	4·3	5·0	4·5	4·1	2·7	.....	.....	.....	.....	.....	4·1			
	3·4	4·4	3·6	3·6	4·1	5·5	.....	.....	.....	.....	.....	4·0	3·2	·123	·092
944	0·8	−0·5	.....	.....	.....	−1·9	−1·1	−0·7	−1·0	−1·1	.....	−0·8			
	−1·8	−2·4	−1·6	0·2	.....	.....	−0·7	0·0	−1·0	−0·7	−1·1	−1·0	.....	·005	
945	5·4	6·4	4·5	4·5	3·8	.....	.....	.....	.....	.....	.....	4·7			
	4·5	5·7	0·6	2·7	7·0	5·2	5·5	6·4	5·6	6·6	5·7	4·8	.....	·049	
946	... ..	.....	3·6	1·5	3·5	.....	.....	.....	.....	.....	.....	3·5			
	.....	.....	3·6	2·1	4·1	.....	.....	.....	.....	.....	.....	3·5	.....	·032	
947	.....	.....	2·3	1·6	2·8	.....	.....	.....	.....	.....	.....	1·8			
	.....	.....	2·3	2·3	2·2	.....	.....	.....	.....	.....	.....	1·7	.....	·021	·033
948	.....	.....	−2·0	−0·6	−2·9	.....	.....	.....	.....	.....	.....	−2·5			
	−1·4	.....	0·0	−2·8	−1·6	.....	.....	.....	.....	.....	.....	−1·5	−1·7	·003	·019
949	3·0	.....	1·4	3·0	0·4	0·7	.....	.....	.....	.....	.....	1·3			
	.....	.....	1·6	1·0	0·1	1·8	.....	.....	.....	.....	.....	0·5	−1·6	·016	
950	−0·6	0·6	0·2	0·3	2·3	0·0	0·4	0·5	0·5	−0·3	1·7	0·6			
	0·2	0·2	1·2	0·6	2·5	1·8	1·7	.....	.....	2·6	.....	1·4	.....	·013	
951	2·9	3·6	0·4	−1·3	0·0	−0·3	1·9	1·7	−1·4	−0·7	.....	0·6			
	0·9	2·4	−0·9	−0·7	0·1	0·9	3·4	2·6	−1·5	−0·8	−1·1	0·6	.....	·010	
952	3·1	3·0	0·9	1·9	0·6	1·5	2·9	2·1	1·6	2·7	.....	1·9			
	0·6	1·2	3·1	1·9	2·7	2·2	3·4	.....	.....	1·6	.....	2·1	.....	·017	
953	0·8	−1·4	.....	−1·6	.....	−1·9	0·2	1·5	−0·9	−0·9	.....	−0·7			
	1·0	−0·7	−1·6	−0·8	.....	0·9	−0·4	0·9	−1·2	−0·4	−0·2	−0·2	.....	·006	
954	0·5	0·0	.....	−1·2	.....	−3·2	−2·2	−1·4	−1·0	.....	.....	−1·2 :			
	.....	−0·4	.....	.....	.....	.....	−1·9	−1·4	−1·2	−0·5	−1·1	−1·1 :	.....	·003	
955	.....	.....	−0·4	.....	1·4	.....	.....	.....	.....	.....	.....	0·5 :			
	.....	.....	−2·0	0·0	.....	.....	.....	.....	.....	.....	.....	0·2 :	.....	·006	
956	3·9	2·5	3·8	4·5	2·8	2·4	3·7	2·1	2·4	3·4	.....	2·9			
	4·2	4·2	3·1	1·1	1·7	2·2	3·9 :	3·0 :	−1·2 :	2·5	.....	2·2	.....	·017	
957	.....	.....	2·5	2·8	3·8	.....	.....	.....	.....	.....	.....	3·0			
	3·6	.....	2·6	1·5	2·9	.....	.....	.....	.....	.....	.....	3·0	.....	·025	
958	0·0	1·0	2·0	0·6	2·8	0·6	0·6	0·9	−0·3	2·0	.....	1·1			
	1·8	1·4	1·5	1·1	2·8	2·2	0·8	0·9	−0·7	2·0	.....	1·5	.....	·011	
959	−0·6	−1·7	.....	−1·5	.....	−0·8	−2·0	−2·2	−2·6	−1·9	.....	−1·7			
	−0·3	−2·1	−0·1	0·2	−1·7	−1·8	−0·7	−1·5	−2·0	−2·6	−2·1	−1·3	−2·9	·008	−·003
960	2·5	4·6	.....	0·0	3·8	0·5	2·8	3·7	0·2	1·5	.....	2·4			
	1·6	3·6	−0·9	−1·2	2·0	1·9	4·4	.....	.....	1·8	.....	1·7	.....	·015	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
961	Boss 5433	61¹ Cygni	21 02·4	38 15	5·6	K8	5·269	−49·2	8·0 6·8	7·2 8·7:	....
962	Boss 5434	61² Cygni	21 02·4	38 15	6·3	K8	5·155	−47·7	....	..... 7·7:	....
963	Boss 5436	63 Cygni	21 03·2	47 15	4·9	K8	·018	−10·1	....	....	....
964*	Boss 5443	γ Equulei	21 05·5	09 44	4·8	F1:	·172	− 2·6	−1·5 −3·2	−2·5 −4·0:	−3·0 −1·5
965	Boss 5452	ζ Cygni	21 08·7	29 49	3·4	G5	·061	+32·1	−2·1 −3·1	−2·0 −1·8	....
966	Boss 5455	δ Equulei AB	21 09·6	09 36	5·1†	F6	·308	+46·2	5·9 5·2	4·6 4·3	4·0 3·7
967	Boss 5459	.....	21 10·4	40 44	7·2	G3	·045	+ 3·0	−0·1 0·6	3·1 2·6	−0·6 −0·8
968	Boss 5460	τ Cygni	21 10·8	37 37	3·8	F1*n*	·455	−18·7	1·3 1·0	2·0 2·6	0·3 1·4
969	Boss 5461	α Equulei	21 10·8	04 50	4·5†	F4	·107	− 6·	0·5 0·4	−0·8 −0·8	4·9 5·0
970	Boss 5472	.....	21 14·3	55 22	6·2	K5	·027	− 4·5	....	....	....
971	Boss 5479	.....	21 16·2	06 56	6·0	M0	·047	− 6·3	....	....	....
972	H.R. 8170	.....	21 17·2	39 55	6·5	F8	.....	.....	4·5 4·9	4·8 4·6	4·1 4·2
973	Boss 5489	1 Pegasi	21 17·5	19 23	4·2	K0	·120	−61·9	4·0 2·5	2·5 2·6	....
974	Boss 5495	.....	21 18·5	48 58	5·9	K0	·075	+11·9	..... 1·2	1·0 2·4	....
975	H.R. 8191	.....	21 19·6	09 44	6·4	F4*n*	.....	.....	−1·2 0·2	−0·7 0·8	−0·8 −1·1
976	H.R. 8197	.....	21 19·9	24 06	6·4	K1	.....	.....	−0·6 −0·4	2·0 1·8	....
977	Boss 5504	.....	21 20·1	25 45	5·7	A9	·042	+ 7·5	1·7 2·1	2·4 3·6	1·6 1·1
978	H.R. 8210	.....	21 21·8	18 58	6·1	A5	.....	.....	1·5 3·4	3·4 4·9	4·1 3·1
979	Boss 5519	.....	21 23·8	31 47	5·7	F2	·137	−10·6	4·3 3·8	3·4 4·8	2·7 2·0
980	Boss 5522	2 Pegasi	21 25·5	23 12	4·8	M0	·021	− 4·7	−0·2 0·1	....	....
981	Boss 5523	71 Cygni	21 25·8	46 06	5·3	G8	·113	− 4·0	2·5 1·6	1·9 3·0	....
982	Boss 5527	β Aquarii	21 26·3	−06 01	3·1	F8	·020	+16·0	−2·9 −2·4	−3·6	−2·7 −2·2
983	H. R. 8242	.....	21 28·1	52 11	6·2	F4	.....	.....	0·9 1·3	−0·8 −0·2	2·7 3·6
984	Boss 5543	ρ Cygni	21 30·2	45 09	4·2	G4	·100	+21·5	1·8 2·8	1·4 1·1	1·2 1·1

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
961	8·4	9·0	.....	8·2	.....	.....	.....	.....	7·9	7·7	.....	**8·0**			
	8·3	8·6	6·8	8·9	8·6	6·2	9·0:	9·1	7·6	7·6	8·3	**8·0**	8·3	**·302**	·307
962	7·9	9·0	....	8·1	.....	.....	8·0	8·0	8·1	8·4	.....	**8·2**			
	8·2	8·3	8·5	7·4	8·3:	8·0	8·1	8·6	8·0	8·4	8·8	**8·2**	8·7	**·240**	·307
963	−0·2	−1·4	.....	−1·1	.....	−1·6	−0·2	−1·1	−1·5	−0·6	.....	**−0·9**			
	0·2	−0·5	−0·6	−0·8	.....	0·3:	−1·2	−0·9	−1·3	0·8	−0·1	**−0·4**	.....	**·008**	
964	.....	.....	−0·6	.....	3·0	.....	.....	.....	.....	.....	.....	**−0·9**			
	.....	.....	1·2	0·8	1·1	.....	.....	.....	.....	.....	.....	**−0·7**	−0·4	**·007**	
965	−0·6	1·0	−0·2	−0·7	0·8	.....	.....	.....	.....	.....	.....	**−0·5**			
	1·6	0·5	0·6	0·0	.....	0·5	0·3	0·6	.....	.....	.....	**−0·1**	−1·1	**·018**	·026
966	.....	.....	4·6	3·8	3·4	.....	.....	.....	.....	.....	.....	**4·3**	.....		
	.....	.....	3·1	2·5	4·1	.....	.....	.....	.....	.....	.....	**3·8**	4·0	**·062**	·053
967	0·7	0·6	0·7	2·5	0·9	.....	.....	.....	.....	.....	.....	**1·0**			
	2·6	0·2	0·4	−0·4	−1·4	0·2	.....	.....	.....	.....	.....	**0·4**	.....	**·005**	
968	.....	.....	2·3	3·2	4·0	.....	.....	.....	.....	.....	.....	**2·2**			
	.....	.....	2·2	.....	.....	.....	.....	.....	.....	.....	.....	**1·7**	1·9	**·043**	·042
969	.....	.....	1·7	−2·2	3·0	.....	.....	.....	.....	.....	.....	**1·2:**			
	.....	.....	1·4	0·4	2·6	.....	.....	.....	.....	.....	.....	**1·5:**	1·9	**·023**	·034
970	−0·7	−0·5	.....	−1·4	.....	−3·6	0·0	−0·7	−0·8	−0·4	.....	**−1·0**			
	−1·3	−1·9	−2·3:	−1·7	.....	.....	0·3	0·4	−0·7	0·1	0·2	**−0·8**	.....	**·004**	
971	.....	.....	.....	.....	.....	.....	−2·0	−2·1	−1·1	−1·8	.....	**−1·7:**			
	−1·0	−1·8	.....	.....	.....	.....	−0·5	−0·6	−1·9	+0·9	−1·1	**−1·1:**	.....	**·003**	
972	6·4	.....	3·9	5·4	3·3	.....	.....	.....	.....	.....	.....	**4·6**			
	5·5	.....	4·5	3·2	4·7	.....	.....	.....	.....	.....	.....	**4·5**	.....	**·041**	
973	2·2	1·6	2·8	0·7	2·8	0·6	0·8	2·3	2·4	0·7	.....	**1·9**			
	1·2	1·6	3·4	1·1	2·0	0·8	3·4	2·7	2·6	3·3	.....	**2·3**	1·4	**·038**	·020
974	2·1	0·8	0·2	1·0	0·8	.....	0·4	1·4	1·6	2·2	.....	**1·2**			
	0·9	0·1	−0·8	−0·8	.....	1·2	0·8	.....	.....	2·5	.....	**0·8**	.....	**·010**	
975	.....	.....	−1·9	.....	1·5	.....	.....	.....	.....	.....	.....	**−0·6:**			
	.....	.....	−1·3	.....	0·4	.....	.....	.....	.....	.....	.....	**−0·2:**	.....	**·004**	
976	1·6	3·5	0·4	−2·0	2·2	1·0	2·9	2·5	1·2	2·7	.....	**1·5**			
	0·6	2·2	−1·7	−2·7	2·4	2·1	1·9	2·2	0·6	2·0	.....	**0·9**	.....	**·009**	
977	.....	.....	0·8	.....	2·7	.....	.....	.....	.....	.....	.....	**1·8**			
	.....	.....	1·8	0·0	1·1	.....	.....	.....	.....	.....	.....	**1·8**	.....	**·016**	
978	.....	.....	2·3	.....	1·5	.....	.....	.....	.....	.....	.....	**2·6**			
	.....	.....	2·5	1·8	1·2	.....	.....	.....	.....	.....	.....	**2·8**	.....	**·021**	
979	.....	.....	3·9	3·7	3·0	.....	.....	.....	.....	.....	.....	**3·5**			
	.....	.....	2·7	3·2	2·7	.....	.....	.....	.....	.....	.....	**3·2**	2·9	**·034**	·032
980	.....	.....	.....	1·2	.....	0·4	−0·3	−0·1	0·8	0·6	0·2	**0·3**			
	.....	0·0	0·5	2·2	.....	0·2	−1·6	−1·1	−0·1	0·0	0·2	**0·0**	0·6	**·012**	
981	3·0	1·4	1·3	1·7	0·0	1·2	0·9	1·2	0·8	2·4	.....	**1·5**			
	1·2	1·0	2·4	2·6	1·2	0·6	1·9	0·7	.....	1·8	.....	**1·6**	1·5	**·018**	·036
982	.....	.....	−4·2	0·0	−2·2	.....	.....	.....	.....	.....	.....	**−2·6**			
	.....	.....	−4·5	−2·0	−2·2	.....	.....	.....	.....	.....	.....	**−2·6**	−2·1	**·007**	−·016
983	.....	.....	1·3	.....	0·7	.....	.....	.....	.....	.....	.....	**1·0**			
	.....	.....	0·1	−2·0	0·5	.....	.....	.....	.....	.....	.....	**0·6:**	.....	**·008**	
984	0·8	1·0	3·0	3·0	3·0	.....	.....	.....	.....	.....	.....	**1·9**			
	1·5	1·0	1·8	2·1	4·0	0·2	.....	1·5	.....	.....	.....	**1·7**	1·3	**·033**	·013

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
985	Boss 5546	72 Cygni	21 30·7	38 05	5·0	G9	·149	−50·0	1·5 2·6	1·0 1·4	....
986*	H. R. 8257	.....	21 30·9	27 46	7·1†	F3	.....	.....	2·2 2·6	1·7 2·0	3·0 2·4
987	H. R. 8272	.....	21 33·6	44 14	6·1	A4	.....	.....	1·5 2·4	2·1 3·6	3·2 2·8
988	Boss 5560	25 Aquarii	21 34·5	01 48	5·3	G8	·089	−24·0	2·1 2·8	1·0 1·6	....
989	Boss 5567	.....	21 36·3	42 49	5·4	M0	·056	−15·1	−0·8	....	....
990	Boss 5584	ε Pegasi	21 39·3	09 25	2·5	K2	·028	+16·7	−3·0 −4·0	..... −1·4	....
991	Boss 5587	μ^1Cygni A	21 39·6	28 18	4·7	F5	·375	+32·3	3·5 3·9	2·4 2·1	3·7 4·0
992	Boss 5590	9 Pegasi	21 39·8	16 54	4·5	G8	·033	−11·5	−1·3 −3·4	−0·3 −0·7	....
993	Boss 5592	κ Pegasi	21 40·1	25 11	4·8†	F2	·036	+ 3·5	2·5 3·1	1·6 1·9	3·8 2·6
994	Boss 5593	μ Cephei	21 40·4	58 19	4·5	M2	·005	+36·2	−4·9	....	....
995	Boss 5619	.....	21 46·4	60 49	6·4	M1	·019	− 6·3	....	....	....
996	Boss 5620	.....	21 46·8	66 20	6·8	F2	.....	.....	1·0 2·1	1·5 1·8	0·7 0·4
997	Boss 5651	Lal. 42883	21 54·3	29 21	6·8	F7	·540	+19·6	5·7 5·3	5·7 6·6	4·7 4·7
998	Boss 5661	.....	21 57·8	72 42	5·2	F4	·174	−21·3	3·1 3·1	2·8 2·1	3·2 2·4
999	Boss 5673	.....	22 00·6	26 12	5·9	K2	·050	−15·7	1·1 1·2	2·2	....
1000	Boss 5674	ν Pegasi	22 00·6	04 34	4·9	K9	·146	− 6·3	....	....	....
1001	Boss 5676	α Aquarii	22 00·6	−00 48	3·2	F9	·018	+15·6	−2·4 −2·4	−1·2 −0·6	−1·8 −2·1
1002	Boss 5678	.....	22 00·8	62 38	5·5	M4	·053	+ 6·5	....	....	....
1003	Boss 5679	ξ^2 Cephei br.	22 00·9	64 08	4·4	A4	·233	+ 8·2	2·5 1·4	1·4	3·0 2·3
1004	H. R. 8421	.....	22 01·3	46 16	6·3	M8	.....	.....	−1·0 −1·4	....	....
1005	Boss 5688	ι Pegasi	22 02·4	24 51	4·0	F4	·302	+ 7·8	3·3 2·9	3·4 4·1	4·4 4·6
1006	Boss 5691	.....	22 02·7	18 59	5·8	F2	·129	− 6·1	2·6 2·6	3·6 4·0	2·0 1·4
1007	H. R. 8441	.....	22 03·7	25 03	6·0	A9	.....	.....	2·0 1·2	2·8 3·3	1·3 1·1
1008	H. R. 8445	.....	22 04·3	49 18	6·6	K2	.....	.....	..... −2·4	..... −3·3	....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
985	2·3	0·9	.....	0·5	4·1	1·3	1·3	0·8	1·6	2·2	.....	**1·6**			
	1·3	0·3	2·2	1·5	2·1	2·0	1·5	2·8	1·0	1·1	.....	**1·6**	0·6	**·021**	·003
986	.....	.....	−0·6	1·5	3·3	.....	.....	.....	.....	.....	.....	**1·9**			
	.....	.....	2·8	2·4	0·9	.....	.....	.....	.....	.....	.....	**2·2**	.....	**·010**	
987	.....	.....	1·5	2·5	1·0	.....	.....	.....	.....	.....	.....	**2·0**			
	.....	.....	1·8	2·0	0·6	.....	.....	.....	.....	.....	.....	**2·2**	.....	**·016**	
988	0·6	1·3	0·0	3·0	1·7	1·5	−0·6	0·3	−0·5	0·4	.....	**0·9**			
	1·6	0·2	0·2	0·3	1·8	1·4	0·4	−0·3	1·0	1·2	.....	**1·0**	1·9	**·013**	
989	.....	.....	.....	0·6	.....	0·2	0·6	0·4	0·5	−0·7	−0·3	**0·1**			
	.....	−0·1	−2·1	−0·5	.....	1·1	0·0	0·3	−0·9	−0·6	0·1	**−0·3**	.....	**·008**	
990	0·5	−3·2	−1·4	−3·5	.....	−1·9	0·0	−1·0	−2·5	−2·1	.....	**−1·8**			
	−3·1	−2·9	0·0	−0·7	−1·9	−1·5	0·6	0·0	−1·4	−2·6	−1·1	**−1·5**	−0·3	**·015**	·006
991	.....	.....	4·4	3·2	3·3	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	2·7	3·7	4·0	.....	.....	.....	.....	.....	.....	**3·4**	3·5	**·056**	·046
992	−0·2	.....	−1·6	1·3	−1·0	0·7	1·5	−1·6	−3·0	−0·3	.....	**−0·5**			
	.....	−1·5	0·4	−0·6	1·8	1·8	1·5	0·0	−1·0	−0·2	.....	**−0·2**	−0·6	**·011**	
993	.....	.....	3·9	1·7	1·0	.....	.....	.....	.....	.....	.....	**2·4**			
	.....	.....	2·9	1·6	2·2	.....	.....	.....	.....	.....	.....	**2·4**	2·7	**·033**	·038
994	.....	.....	.....	−5·5	.....	−4·7	−6·9	−5·6	−4·8	−4·0	−5·1	**−5·2**			
	.....	−3·8	−3·2	−5·2	.....	−4·1	−6·0	−5·8	−5·4	−3·6	−4·6	**−4·6**	0·3	**·001**	·010
995	.....	.....	.....	−0·8	.....	1·2	−1·1	−0·1	1·8	−0·1	0·3	**0·2**			
	.....	.....	.....	−0·9	.....	0·5	0·0	0·7	−0·4	−0·8	0·2	**−0·1**	.....	**·005**	
996	.....	.....	2·1	2·6	0·7	.....	.....	.....	.....	.....	.....	**1·4**			
	.....	.....	1·4	2·1	0·4	.....	.....	.....	.....	.....	.....	**1·4**	.....	**·008**	
997	5·3	.....	5·3	5·0	4·0	.....	.....	.....	.....	.....	.....	**5·1**			
	5·5	.....	4·0	4·1	3·6	.....	.....	.....	.....	.....	.....	**4·8**	4·1	**·043**	·040
998	.....	.....	2·8	4·0	2·8	.....	.....	.....	.....	.....	.....	**3·1**			
	.....	.....	2·9	4·2	2·8	.....	.....	.....	.....	.....	.....	**2·9**	2·6	**·036**	·038
999	0·0	0·0	−0·5	−1·3	.....	0·0	0·6	0·5	−0·1	0·2	.....	**0·2**			
	0·9	1·2	−0·4	−1·0	−0·3	1·1	−0·6	0·5	−0·7	0·9	−0·2	**0·2**	.....	**·007**	
1000	.....	.....	.....	1·6	.....	0·2	−0·5	−1·1	−0·2	2·4	1·2	**0·6**			
	−1·3	−0·5	−0·4	0·0	2·3	0·6	−0·2	−0·6	−0·2	1·6	0·9	**0·2**	0·3	**·012**	·016
1001	.....	.....	−3·7	−1·2	−1·5	.....	.....	.....	.....	.....	.....	**−2·0**			
	.....	.....	−3·4	−1·0	−0·3	.....	.....	.....	.....	.....	.....	**−1·6**	−2·8	**·010**	·010
1002	.....	.....	.....	−2·0	.....	−0·2	−3·5	−1·7	−1·0	−1·0	−1·5	**−1·6**			
	.....	.....	.....	−1·0	.....	−1·2	−2·7	−0·6	−1·6	−1·2	−1·7	**−1·4**	.....	**·004**	
1003	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**2·3:**			
	.....	.....	2·9	3·1	1·2	.....	.....	.....	.....	.....	.....	**2·2:**	.....	**·037**	·035
1004	.....	.....	.....	0·5	.....	0·3	−2·9	−3·0	−0·8	−0·6	−2·1	**−1·2**			
	.....	−1·6	−3·8	−1·6	.....	−0·6	−0·2	0·2	−2·0	−0·7	−1·2	**−1·3**	.....	**·003**	
1005	.....	.....	3·2	3·5	3·3	.....	.....	.....	.....	.....	.....	**3·4**			
	.....	.....	3·3	3·6	2·2	.....	.....	.....	.....	.....	.....	**3·4**	3·6	**·076**	·079
1006	.....	.....	3·4	3·6	3·8	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	2·4	2·3	2·8	.....	.....	.....	.....	.....	.....	**2·6**	2·4	**·026**	·013
1007	.....	.....	0·1	.....	2·7	.....	.....	.....	.....	.....	.....	**1·8**			
	.....	.....	1·8	2·2	2·7	.....	.....	.....	.....	.....	.....	**2·0**	.....	**·015**	
1008	0·8	.....	.....	−0·8	.....	−1·2	−2·0	−2·6	−2·2	−2·8	.....	**−1·5:**			
	.....	−1·1	−1·7	−2·1	.....	.....	−0·6	−1·2	−3·1	−1·2	.....	**−1·9**	.....	**·002**	

80600—9½

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
1009	Boss 5709	π Pegasi	22 05·5	32 41	4·4	A9*n*	·027	+ 5·3	0·6 0·2	−1·8 −0·8	−1·5 0·1
1010	H. R. 8460	.....	22 06·3	30 04	6·4	A5*n*	.....	.....	−0·5 1·4	0·3 2·8	1·1 2·3
1011	Boss 5714	ζ Cephei	22 07·4	57 42	3·6	K3	·014	− 5·1	−2·6 −1·8	..... −1·2	....
1012	H. R. 8466	.....	22 07·5	24 28	6·1	K5	.....	.....	−1·9: −0·6:	....	....
1013	Boss 5716	24 Cephei	22 07·9	71 51	5·0	G7	·031	−2·0	0·6 0·3	0·2 0·0	....
1014	Boss 5721	.....	22 08·2	56 21	5·4	F6	·271	−5·9	3·5 3·3	3·6 3·0	4·0 3·5
1015	Boss 5723	.....	22 08·4	69 38	5·5	F4	·055	+11·8	3·9 2·8	3·4 4·4	2·6 2·1
1016	Boss 5724	.....	22 08·4	34 07	5·4	K1	·051	+ 5·4	0·3 1·0	2·2 2·5	....
1017	Boss 5727	.....	22 08·7	60 16	5·5	K1	·025	+ 8·9	1·0 0·5	1·2	....
1018	Boss 5732	Lacertae	22 09·6	39 13	4·6	K7	·052	+ 2·0	..... −0·2:	....	....
1019	Boss 5746	1 Lacertae	22 11·6	37 15	4·2	K4	·024	+4·9	−0·6 −0·9	....	....
1020	Boss 5751	.....	22 12·8	56 43	6·0	G6	·048	+4·3	0·8 −0·6	−0·6 −0·2	....
1021	Boss 5754	.....	22 14·6	37 15	6·1	F1	·093	+18·6	0·8 1·2	2·6 3·3	2·1 1·8
1022	Boss 5756	.....	22 14·9	62 18	6·0	K2	·051	+ 7·9	1·3 0·5	3·2 2·6	....
1023	H. R. 8514	.....	22 15·9	07 41	6·2	F4	.....	.....	4·3 3·8	3·5 4·2	4·6 4·6
1024	H. R. 8519	.....	22 16·6	50 28	6·6	K2	.....	.....	0·9 −0·4:	..... 0·0	....
1025	Boss 5772	33 Pegasi	22 18·8	20 20	6·1	F6	·341	−13·4	5·8 4·5	4·3 4·3	4·6 4·8
1026	H. R. 8536	.....	22 19·5	38 04	6·2	F5	.....	.....	4·0 3·8	2·0 2·2	4·2 3·7
1027	Boss 5776	3 Lacertae	22 19·6	51 44	4·6	G8	·192	+ 2·4	2·4 3·3	1·0 1·2	....
1028	Boss 5786	34 Pegasi	22 21·5	03 53	5·8	F8	·298	−11·2	4·1 3·8	3·2 2·2	4·2 4·5
1029	Boss 5790	35 Pegasi	22 22·8	04 12	4·9	K1	·328	+62·6	0·5 1·6	2·1 2·0	....
1030	Boss 5797	.....	22 24·1	08 38	5·8	K3	·065	−20·9	....	....	....
1031	Boss 5798	.....	22 24·5	26 16	6·0	K2	·034	−34·7	....	....	....
1032	Boss 5800	.....	22 24·9	03 56	5·5	F2	·143	+ 7·4	1·5 0·3	2·3 2·6	1·7 0·8

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1009	.....	.....	.....	.....	.....	1·5	.....	.....	.....	.....	.....	**−0·3**			
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	**−0·2**:	0·3	·012	·005
1010	.....	.....	.....	0·8	.....	.....	.....	.....	.....	.....	.....	**0·4**			
	.....	.....	1·8	1·8	.....	.....	.....	.....	.....	.....	.....	**2·0**:	.....	·009	
1011	−0·2	−2·4	−3·7	−2·3	.....	−2·2	−0·8	−2·7	−2·9	−2·6	.....	**−2·2**			
	−1·0	−1·6	−1·5	−2·4	−0·6	−2·9	−1·3	−2·8	−2·8	−2·2	−1·5	**−1·8**	0·5	·007	·026
1012	.....	.....	.....	−0·3	.....	0·4	−0·8	−2·0	−1·7	−0·5	.....	**−1·0**:			
	−2·0	−2·0	−1·7	−1·2	0·1	1·1	1·3	−0·3	−1·2	0·4	0·2	**−0·5**	.....	·004	
1013	.....	.....	1·0	3·0	−0·1	1·1	−0·7	0·1	−0·9	0·8	.....	**0·5**			
	.....	1·6	1·0	0·4	1·7	2·2	0·5	0·0	0·2	0·4	.....	**0·8**	−2·0	·013	
1014	.....	.....	3·9	4·1	3·3	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	1·6	2·8	3·4	.....	.....	.....	.....	.....	.....	**2·9**	3·4	·038	·027
1015	.....	.....	2·6	4·0	2·6	.....	.....	.....	.....	.....	.....	**3·2**			
	.....	.....	3·2	2·8	3·8	.....	.....	.....	.....	.....	.....	**3·2**	2·6	·034	·084
1016	1·2	1·8	2·7	1·8	0·8	1·0	1·8	2·8	1·8	1·4	.....	**1·6**			
	1·2	0·5	0·6	0·8	0·4	1·4	2·4	3·8	2·3	2·6	.....	**1·6**	0·8	·017	
1017	0·0	1·0	1·2	0·2	0·0	0·9	−0·3	−0·3	−0·5	0·0	.....	**0·4**			
	0·6	0·5	0·6	−0·8	0·4	2·1	0·5	1·2	−0·3	1·4	.....	**0·6**	.....	·010	
1018	−0·2	0·3	.....	0·7	.....	0·3	0·7	0·8	−0·2	0·6	.....	**0·4**			
	0·2	−0·5	−0·4	−0·4	1·3	1·2	0·2	−0·1	−1·2	0·9	0·9	**0·2**	.....	·014	
1019	0·6	−0·8	.....	−1·4	.....	0·7	−1·5	−2·6	−2·3	−0·5	.....	**−0·9**			
	0·6	−0·9	−0·4	0·0	0·6	−0·4	−0·7	−2·4	−1·0	0·0	0·4	**−0·4**	0·4	·011	·005
1020	0·0	1·0	−0·5	1·3	1·0	1·4	0·0	0·7	0·2	1·3	.....	**0·5**			
	.....	0·3	0·6	−0·2	3·3	1·5	.....	.....	.....	1·3	.....	**0·8**	.....	·009	
1021	.....	.....	2·3	.....	0·5	.....	.....	.....	.....	.....	.....	**1·7**			
	.....	.....	2·1	1·8	1·0	.....	.....	.....	.....	.....	.....	**1·9**	.....	·014	
1022	0·0	1·0	.....	−0·2	0·8	1·6	−0·3	1·0	−0·3	1·8	.....	**0·9**			
	0·3	−0·4	−1·2	−1·2	1·7	0·9	0·3	0·1	−0·7	0·7	−0·5	**0·2**	.....	·008	
1023	.....	.....	2·7	.....	3·3	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	2·4	3·0	2·9	.....	.....	.....	.....	.....	.....	**3·5**	.....	·030	
1024	0·5	−0·9	−2·7	−2·0	.....	0·5	−2·3	−2·9	−2·2	−1·5	.....	**−1·3**:			
	.....	−1·8	−2·4:	−1·8:	.....	2·0:	0·3	−0·4	−2·5	0·0	−0·5	**−0·7**:	.....	·003	
1025	.....	.....	5·7	4·7	4·0	.....	.....	.....	.....	.....	.....	**4·9**			
	.....	.....	4·4	3·7	3·8	.....	.....	.....	.....	.....	.....	**4·2**	4·1	·049	·060
1026	3·4	.....	2·8	3·0	1·9	.....	.....	.....	.....	.....	.....	**3·0**			
	4·2	.....	1·7	0·3	3·1	.....	.....	.....	.....	.....	.....	**2·7**	.....	·021	
1027	2·0	3·0	0·2	1·4	1·7	0·2	0·2	0·9	0·5	−0·1	.....	**1·1**			
	1·8	2·0	0·8	3·3	1·2	1·5	0·5	0·6	0·2	1·2	.....	**1·5**	2·1	·022	·017
1028	4·8	.....	5·5	4·1	2·8	.....	.....	.....	.....	.....	.....	**4·1**			
	3·8	.....	3·9	3·4	2·8	.....	.....	.....	.....	.....	.....	**3·5**	3·9	·040	·067
1029	0·7	3·4	1·6	−0·7	2·8	0·1	2·9	0·8	0·8	3·0	.....	**1·5**			
	2·2	1·7	−1·3	0·0	2·0	0·1	2·9	1·7	0·6	0·1	0·1	**1·1**	1·8	·019	·033
1030	−0·2	0·0	.....	.....	.....	.....	−3·0	−2·0	−2·3	−1·7	.....	**−1·5**:			
	−2·6	−0·5	.....	.....	.....	.....	−2·4	−1·0	−0·7	−1·4	−1·3	**−1·4**:	.....	·004	
1031	1·0	0·0	0·0	−1·7	.....	−1·9	0·8	−0·7	−0·3	−0·4	.....	**−0·4**			
	.....	−0·3	−2·0	−1·2	.....	0·9	1·3	−0·4	−1·4	0·4	−0·5	**−0·4**	.....	·005	
1032	.....	.....	4·0	.....	0·0	.....	.....	.....	.....	.....	.....	**1·9**			
	.....	.....	1·4	2·4	2·5	.....	.....	.....	.....	.....	.....	**1·7**	0·9	·018	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
1033	Boss 5804	5 Lacertae	22 25·4	47 11	4·6	K2	·021	+ 0·2	−4·2 −2·4	..... −1·8	....
1034	Boss 5807	δ Cephei	22 25·5	57 54	4·1	G0	·014	− 4·3	−2·8 −3·0	−3·5 −2·9	−2·9 −2·6
1035	Boss 5823	.....	22 30·1	69 24	6·0	F2	·141	+ 6·1	0·9 0·0	2·1 3·0	1·2 0·9
1036	Boss 5838	31 Cephei	22 33·3	73 07	5·2	F2	·173	+ 5·6	0·3 0·2	1·4 2·0	0·2 0·6
1037	Boss 5840	.....	22 34·0	19 00	5·8	G5	·115	− 9·9	1·2 0·7	1·9 1·6	....
1038	Boss 5843	.....	22 34·7	56 17	5·5	M5	·058	+19·4	−1·0	....	....
1039	Boss 5852	11 Lacertae	22 36·1	43 46	4·6	K3	·100	+ 2·4	0·9 0·8	0·2 0·8	....
1040	Boss 5865	η Pegasi	22 38·3	29 42	3·1	G1	·040	+14·5	2·2 2·0	0·0 −1·2:	3·1 0·8
1041	Boss 5872	45 Pegasi	22 40·6	18 51	6·4	K0	·056	−13·0	0·3 −1·6	1·7	....
1042	Boss 5874	ξ Pegasi	22 41·7	11 40	4·3	F5	·548	+ 2·4	3·5 3·7	3·5 3·9	3·9 4·2
1043	Boss 5875	λ Pegasi	22 41·7	23 02	4·1	G6	·064	+ 5·4	−0·6 1·0	−1·0 −0·4:	....
1044	Boss 5885	μ Pegasi	22 45·2	24 04	3·7	G6	·157	+23·6	0·3 1·2	1·1 1·0	....
1045	H. R. 8692	.....	22 45·9	50 09	6·4	G5	.....	.....	−1·9 0·4	..... −0·5	....
1046	Boss 5891	ι Cephei	22 46·1	65 40	3·7	G9	·140	− 0·7	1·3 2·8	0·5 1·3	....
1047	Boss 5894	σ Pegasi	22 47·4	09 18	5·3	F4	·519	+20·4	3·5 2·9	3·1 3·9	4·1 3·7
1048	Boss 5900	.....	22 48·2	16 19	5·7	K1	·032	− 4·9	−0·3 −0·3	0·9 2·6	....
1049	H. R. 8707	.....	22 49·1	59 34	6·3	G3	.....	.....	2·8 2·6	2·7 3·0	5·0 4·6
1050	H. R. 8712	.....	22 49·5	39 51	5·9	K2	.....	.....	..... 1·0	..... 2·8	....
1051	H. R. 8714	.....	22 49·7	16 24	6·5	M5	.....	.....	....	....	....
1052	H. R. 8718	.....	22 50·4	36 33	6·0	A8	.....	.....	3·7 3·7	1·9 1·0	4·2 3·4
1053	Boss 5917	.....	22 52·5	20 14	5·6	G5	·212	−24·1	3·5 4·4	4·8 4·4	4·0 .....
1054	Boss 5924	2 Piscium	22 54·4	00 26	5·6	K1	·108	− 9·2	....	..... 2·5	....
1055	Boss 5931	.....	22 55·9	56 24	5·5	G3	·008	−49·4	−3·4 −2·3	−4·3 −4·0	−3·3 −2·7
1056*	H. R. 8765	.....	22 57·8	31 14	6·9†	F2	.....	.....	1·9 2·8	2·0 1·1	1·6 2·4

Continued

No.	4455 / 62	4455 / 94	4247 / 50	4258 / 60	4162 / 68	4202 / 07	4455 / 82	4455 / 89	4489 / 94	4494 / 96	4482 / 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1033	.....	−2·3	−4·4	−3·3	.....	−3·5	−3·0	−3·2	−3·4	−4·1	.....	−3·5			
	−3·8	−3·2	−3·2	−2·5	−2·1	−3·1	−2·2 :	−1·3	−4·1	−4·5	−3·8	−2·9	−2·8	·003	·005
1034	.....	.....	−1·6	−2·0	−3·1	.....	.....	.....	.....	.....	.....	−2·7			
	−2·1	.....	−0·4	−1·0	−1·8	−2·8	.....	.....	.....	.....	.....	−2·1	−2·7	·005	·011
1035	.....	.....	0·8	.....	1·1	.....	.....	.....	.....	.....	.....	1·2			
	.....	.....	−0·5	0·6	1·5	.....	.....	.....	.....	.....	.....	0·9	.....	·010	
1036	.....	.....	−1·5	0·6	0·8	.....	.....	.....	.....	.....	.....	0·3			
	.....	.....	−1·5	1·7	1·0	.....	.....	.....	.....	.....	.....	0·5	0·2	·011	−·034
1037	2·2	3·0	0·7	−0·5	0·1	0·3	.....	.....	.....	.....	.....	1·1			
	2·9	1·8	0·9	−1·6	1·9	0·2	−0·2	0·6	0·2	−0·6	.....	0·7	.....	·010	
1038	.....	.....	.....	−2·2	.....	−2·3	−2·6	−1·8	−1·3	−1·2	−2·0	−1·8			
	.....	.....	.....	−1·0	.....	−1·7	−2·0	−1·5	−2·0	−1·5	−1·6	−1·6	.....	·004	
1039	0·5	2·2	0·4	2·4	1·7	−0·5	0·3	0·9	−0·9	−1·0	.....	0·6			
	1·3	2·3	−1·2	0·4	1·1	1·6	1·5	1·6	−0·8	−0·5	−0·9	0·6	0·7	·016	
1040	−1·6	.....	−0·1	−1·0	.....	.....	.....	.....	.....	.....	.....	0·4 :			
	0·0 :	.....	1·4	0·4	.....	−0·7	.....	.....	.....	.....	.....	0·4 :	−0·2	·029	−·003
1041	0·2	1·2	−0·3	−1·2	−0·3	0·6	−1·9	0·1	0·0	−0·3	.....	0·0			
	1·0	0·5	−2·0	−1·5	0·8	1·0	0·0	1·3	0·9	1·0	.....	0·1	.....	·005	
1142	.....	.....	3·0	2·0	3·5	.....	.....	.....	.....	.....	.....	3·2			
	3·3	.....	3·5	0·4	3·7	.....	.....	.....	.....	.....	.....	3·2	3·8	·060	·058
1043	2·0	1·5	0·4	−0·4	0·9	0·9	0·0	0·5	0·0	1·0	.....	0·4			
	1·2	0·0	1·3	0·8	.....	1·0	1·6	2·4	0·6	0·4	.....	0·9	−0·3	·020	·037
1044	0·6	1·7	1·8	0·8	2·4	1·3	.....	.....	.....	.....	.....	1·3			
	2·6	3·1	0·4	1·2	1·0	1·9	2·0	2·0	.....	.....	.....	1·6	1·1	·035	·024
1045	.....	−3·0	−2·9	0·4	−1·3	−0·4	.....	−0·4	−3·0	−1·5	.....	−1·6			
	.....	.....	−0·3	−1·4	−0·7	0·7	.....	0·0	.....	.....	.....	−0·2	.....	·004	
1046	1·8	3·0	1·1	1·4	0·8	1·2	1·8	2·9	2·4	0·7	.....	1·6			
	1·8	0·6	1·6	2·0	1·8	1·5	2·2	1·9	.....	.....	.....	1·7	1·1	·039	·042
1047	.....	.....	5·4	2·2	2·5	.....	.....	.....	.....	.....	.....	3·5			
	.....	.....	3·7	2·5	2·8	.....	.....	.....	.....	.....	.....	3·2	3·2	·041	·042
1048	1·3	.....	0·9	1·0	−0·1	0·2	1·9	1·2	−0·2	0·8	.....	0·7			
	1·7	2·0	−0·7	0·1	0·2	1·5	1·9	1·2	−1·8	0·5	.....	0·7	.....	·010	
1049	5·3	.....	4·7	4·3	3·8	.....	.....	.....	.....	.....	.....	4·1			
	5·1	.....	2·4	3·2	4·7	3·6	.....	.....	.....	.....	.....	3·6	.....	·032	
1050	0·2	1·2	−1·0	1·0	.....	0·5	−0·2	1·0	1·4	2·9	.....	0·8			
	0·6	−0·4	−2·0	−0·2	.....	.....	1·8	−0·4	0·9	2·6	0·0	0·5	.....	·009	
1051	.....	.....	.....	.....	.....	.....	−0·2	−1·7	−0·2	−1·5	−1·4	−1·0 :			
	.....	−2·6	.....	.....	.....	.....	−0·9	0·7	−2·0	−1·8	−1·4	−1·5 :	.....	·003	
1052	.....	.....	3·7	3·0	3·3	.....	.....	.....	.....	.....	.....	3·3			
	.....	.....	2·8	2·6	1·9	.....	.....	.....	.....	.....	.....	2·6	.....	·025	
1053	6·2	.....	3·6	5·3	4·0	.....	.....	.....	.....	.....	.....	4·5			
	5·2	4·2	3·3	3·2	2·8	2·2	.....	.....	.....	.....	.....	3·7	4·6	·050	
1054	1·5	0·6	0·2	0·6	.....	.....	2·0	2·3	2·2	2·9	.....	1·5			
	1·7	−0·4	.....	.....	.....	.....	1·1	2·2	2·3	3·9	1·6	1·9	.....	·016	
1055	.....	.....	−6·0	−5·4	−4·7	.....	.....	.....	.....	.....	.....	−4·5			
	−3·5	.....	−5·2	−5·2	−4·6	.....	.....	.....	.....	.....	.....	−3·6	−2·6	·001	
1056	.....	.....	1·4	0·8	0·9	.....	.....	.....	.....	.....	.....	1·4			
	.....	.....	1·2	1·3	−0·6	.....	.....	.....	.....	.....	.....	1·4	.....	·008	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
1057	Boss 5940	β Pegasi	22 58·9	27 32	2·6	M3	·234	+17·3	.....	.....	.....
									−0·1	.....	.....
1058	Boss 5942	3 Androm.	22 59·7	49 30	4·9	G8	·231	−23·9	2·4	0·6	.....
									2·5	1·2	.....
1059	H. R. 8784	.....	23 00·2	16 02	6·4	G9	.....	.....	4·2	3·8	.....
									3·4	2·9	.....
1060	H. R. 8785	.....	23 00·2	00 46	6·4	G8	.....	.....	.....	.....	.....
									.....	.....	.....
1061	H. R. 8788	.....	23 01·3	17 59	6·1	F4	.....	.....	4·9	3·5	3·9
									4·0	3·4	3·4
1062	Boss 5952	55 Pegasi	23 02·0	08 52	4·7	M0	·019	+ 1·0	.....	.....	.....
									.....	.....	.....
1063	Boss 5954	56 Pegasi	23 02·2	24 56	5·0	K2	·040	−16·9	.....	.....	.....
									.....	.....	.....
1064	H. R. 8799	.....	23 02·6	20 37	5·9	A4	.....	.....	1·9	2·8	3·9
									3·1	4·4	3·2
1065	Boss 5966	π Cephei	23 04·7	74 51	4·7†	G2	·030	−10·2	0·6	1·6	−0·6
									1·9	1·2	0·3
1066	Boss 5974	60 Pegasi	23 06·9	26 18	6·4	K0*n*	·228	− 2·5	0·7	2·5	.....
									1·6	.....	.....
1067	Boss 5975	7 Androm.	23 08·0	48 51	4·6	F1	·134	+22·9	2·6	3·6	2·8
									2·9	4·9	2·4
1068	Boss 5976	Br. 3077	23 08·5	56 37	5·6	K5	2·105	− 9·9	6·7	6·9	.....
									8·6	7·4	.....
1069	Boss 5988	γ Piscium	23 12·0	02 44	3·8	G4	·755	− 8·6	1·6	0·2	2·0
									3·4	0·8	3·6
1070	Boss 5989	.....	23 12·1	52 40	5·6	F8	·273	−18·2	4·6	4·1	5·6
									5·0	4·4	5·9
1071	Boss 5990	.....	23 12·5	44 37	6·6	K0	·130	−29·2	2·2	3·5	.....
									0·4	2·7	.....
1072	Boss 5993	8 Androm.	23 13·1	48 28	5·0	M2	·040	+ 4·4	.....	.....	.....
									.....	.....	.....
1073	Boss 6000	ο Cephei	23 14·5	67 34	5·0†	G7	·067	− 7·3	2·2	0·6	.....
									4·4	0·3	.....
1074	Boss 6001	.....	23 14·8	48 04	5·4	K0	·059	+20·3	1·1	.....	.....
									1·2	1·4	.....
1075	Boss 6008	12 Androm.	23 16·1	37 38	5·8	F4	·143	− 0·4	2·9	3·3	4·3
									3·8	2·8	3·7
1076	Boss 6015	66 Pegasi	23 18·0	11 46	5·3	K4	·033	+ 0·7	0·4	2·0	.....
									1·4	.....	.....
1077	Boss 6024	υ Pegasi	23 20·4	22 51	4·6	F6	·195	− 2·4	−0·3	1·2	−1·7
									0·9	1·2	0·3
1078*	Boss 6033	9 Piscium	23 22·1	00 34	6·4	K0	·058	− 5·7	.....	.....	.....
									.....	.....	.....
1079	Boss 6037	θ Piscium	23 22·9	05 50	4·4	G8	·136	+ 9·8	.....	2·0	.....
									.....	.....	.....

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1057	.....	.....	.....	−1·8	.....	−1·5	−0·7	−1·0	−2·6	−1·9	−2·1	**−1·6**			
	.....	−2·9	−2·4	−1·2	.....	−1·2	−1·4	−1·2	−2·4	−1·6	−1·4	**−1·6**	0·0	**·014**	·000
1058	2·4	0·7	1·3	1·7	0·0	0·9	2·0	2·6	2·4	1·0	.....	**1·5**			
	2·8	2·3	0·4	2·0	0·8	1·5	1·9	1·4	.....	0·3	.....	**1·6**	1·3	**·021**	−·004
1059	5·4	4·8	1·7	3·5	1·7	1·6	3·3	2·5	.....	1·7	.....	**3·1**			
	3·8	1·7	0·4	2·0	.....	2·1	2·9	3·1	.....	3·1	.....	**2·5**	.....	**·019**	
1060	3·9	1·2	.....	0·7	.....	.....	0·8	0·7	1·2	2·0	.....	**1·5**			
	4·3	2·0	.....	.....	.....	.....	0·8	0·4	.....	3·6	.....	**2·2**:	.....	**·012**	
1061	.....	.....	2·9	4·5	3·6	.....	.....	.....	.....	.....	.....	**3·9**			
	.....	.....	2·1	2·5	3·8	.....	.....	.....	.....	.....	.....	**3·2**	.....	**·031**	
1062	.....	.....	.....	−0·4	.....	−1·2	−3·4	−1·7	0·8	1·6	0·9	**−0·5**	.....	.....	
	.....	0·2	0·5	1·2	.....	0·2	−1·0	−0·4	−0·4	−0·1	0·2	**0·0**	0·3	**·010**	·005
1063	−1·5	−0·9	−0·7	−1·3	−1·4	−1·9	−0·7	−1·7	−2·8	−2·3	.....	**−1·5**			
	−3·7	−1·9	0·0	−1·2	−0·9	−0·2	0·0	−0·8	−1·8	−1·3	−1·9	**−1·3**	1·9	**·005**	
1064	.....	.....	3·1	.....	.....	.....	.....	.....	.....	.....	.....	**3·0**:			
	.....	.....	2·7	1·6	3·0	.....	.....	.....	.....	.....	.....	**3·0**:	.....	**·026**	
1065	3·1	.....	3·0	2·8	1·4	.....	.....	.....	.....	.....	.....	**1·7**			
	0·8	0·1	4·0	1·7	4·3	2·4	.....	.....	.....	.....	.....	**1·8**	−0·2	**·026**	−·014
1066	1·6	1·5	0·4	2·3	0·8	0·3	−1·0	0·8	−0·1	1·5	.....	**1·0**			
	2·0	1·2	0·3	0·4	1·2	2·0	−0·8	0·3	.....	1·0	.....	**0·9**	.....	**·008**	
1067	.....	.....	2·3	3·6	1·2	.....	.....	.....	.....	.....	.....	**2·7**			
	.....	.....	2·2	1·8	1·5	.....	.....	.....	.....	.....	.....	**2·6**	2·3	**·041**	·048
1068	6·5	7·7	.....	7·2	.....	.....	6·7	6·6	5·6	6·1	.....	**6·7**			
	5·8	5·7	7·0	6·6	6·0	6·4	6·1	6·6	6·6	5·7	6·5	**6·5**	7·2	**·158**	·172
1069	1·8	.....	−1·0	−0·5	2·0	.....	.....	.....	.....	.....	.....	**0·9**			
	.....	0·4	−0·4	−1·2	−0·1	.....	.....	.....	.....	.....	.....	**0·9**	0·5	**·026**	·021
1070	4·4	.....	4·5	5·1	5·2	.....	.....	.....	.....	.....	.....	**4·8**			
	3·2	.....	4·6	5·8	5·2	.....	.....	.....	.....	.....	.....	**4·9**	3·9	**·070**	·062
1071	3·1	1·2	2·1	3·5	2·8	2·4	0·8	1·0	1·6	2·7	.....	**2·2**			
	2·6	1·2	−0·6	0·4	2·0	1·2	0·8	.....	−0·3	3·6	.....	**1·3**	.....	**·011**	
1072	.....	.....	.....	−0·2	.....	−0·6	−0·2	−2·1	−0·5	−0·9	−0·6	**−0·7**			
	.....	0·0	−1·0	−0·2	.....	−0·7	−0·9	−0·9	−1·0	−1·0	−0·1	**−0·6**	0·2	**·007**	
1073	1·6	2·3	2·1	3·7	0·3	0·9	0·8	2·7	0·8	0·4	.....	**1·5**			
	0·1	3·2	1·9	2·7	1·7	1·5	1·5	2·5	0·9	1·2	.....	**1·8**	0·7	**·021**	·032
1074	2·2	2·3	0·4	0·4	1·7	1·4	1·9	1·2	−0·9	0·3	.....	**1·1**			
	1·4	1·4	0·1	0·4	1·6	2·0	0·0	0·9	0·2	1·4	.....	**1·0**	.....	**·013**	
1075	.....	.....	4·7	3·9	3·1	.....	.....	.....	.....	.....	.....	**3·7**			
	.....	.....	2·5	2·8	3·9	.....	.....	.....	.....	.....	.....	**3·2**	.....	**·034**	
1076	0·6	1·2	.....	0·8	−0·7	1·1	0·9	0·8	0·1	0·4	.....	**0·7**			
	2·0	1·6	−1·4	0·1	0·4	1·8	2·2	1·8	0·2	1·2	.....	**1·0**	.....	**·013**	
1077	.....	.....	−0·6	2·2	0·7	.....	.....	.....	.....	.....	.....	**0·2**			
	.....	.....	−0·9	2·1	1·4	.....	.....	.....	.....	.....	.....	**0·8**	1·3	**·015**	·025
1078	.....	.....	.....	.....	.....	.....	−0·2	−0·2	−0·9	0·5	.....	**−0·2**:			
	0·6	0·8	.....	.....	.....	.....	0·0	1·3	.....	1·6	.....	**0·8**:	.....	**·006**	
1079	0·0	2·1	0·4	−1·2	0·8	1·0	1·7	1·6	0·0	0·8	.....	**0·8**			
	1·2	1·0	−0·4	−2·1	.....	−0·2	0·4	.....	−1·0	0·8	.....	**0·0**:	.....	**·016**	

TABLE 7—

No.	Star	Name	α (1900) h m	δ (1900) ° ′	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
1080	Boss 6040	70 Pegasi	23 24·1	12 13	4·7	K0	·064	− 9·3	−1·3 0·1	2·7 2·4	....
1081	H. R. 8925	.....	23 25·3	48 36	6·4	K7	.....	.....	..... 0·6	....	....
1082	Boss 6049	14 Androm.	23 26·3	38 42	5·3	G9	·296	−50·0	3·1 1·5	1·0 1·4	....
1083	.....	C. 3081	23 26·5	58 37	6·8	K1	1·060	−14·8	6·3 5·4	5·4 5·7	....
1084*	Boss 6058	.....	23 28·5	21 57	5·5	M6	·037	+ 8·1	0·0	....	....
1085	Boss 6064	15 Piscium	23 30·4	00 45	6·6	K4	·050	+ 7·6	....	....	....
1086	H. R. 8955	.....	23 31·5	32 21	6·3	F2	.....	.....	2·2 2·0	2·3 2·5	1·4 1·2
1087	Boss 6071	λ Androm.	23 32·7	45 55	4·0	G6	·452	+15·6	4·2 4·2	2·1 2·3	....
1088	Boss 6077	ι Piscium	23 34·8	05 05	4·3	F7	·578	+ 8·5	1·9 2·5	4·0 3·9	3·7 3·3
1089	H. R. 8973	.....	23 35·1	37 06	6·2	F2	.....	.....	2·7 3·4	1·2 2·3	2·4 2·0
1090	Boss 6078	γ Cephei	23 35·2	77 04	3·4	K1	·167	−31·3	3·8 4·0	1·6 2·1	....
1091	Boss 6094	78 Pegasi	23 39·0	28 49	5·0	G9	·083	+ 1·2	−0·3 −0·4	2·1 1·2	....
1092	Boss 6097	.....	23 40·0	55 16	6·6	G7	·032	+17·2	0·0 0·9	−0·4 0·6	....
1093	Boss 6112	.....	23 44·3	58 25	6·4	F2*n*	·060	+38·5	3·3 2·7	1·5 2·0	2·2 2·2
1094	H. R. 9024	.....	23 44·6	35 53	5·9	G0	.....	.....	1·1 2·9	1·8 1·1	2·3 2·5
1095	Boss 6121	.....	22 46·2	08 46	6·1	M3	·064	− 7·3	....	....	....
1096	Boss 6127	φ Pegasi	23 47·4	18 34	5·2	M4	·049	− 6·4	−1·0 −0·6	....	....
1097	Boss 6135	ρ Cassiop.	23 49·4	56 57	4·8	G6	·004	−33·6	−6·0 −5·2	−4·2 −2·1	....
1098	Boss 6141	.....	23 50·5	52 11	6·8	K4	·072	+ 7·2	2·1 2·4	....	....
1099	H. R. 9053	.....	23 50·6	46 48	6·1	K0	.....	.....	−3·4 −2·6	−1·0 0·4	....
1100	Boss 6148	.....	23 52·1	55 09	6·4†	F5	·020	+19·6	1·5 3·4	2·5 1·7	3·7 4·1
1101	Boss 6156	ω Piscium	23 54·2	06 19	4·0	F4	·190	+ 0·3	1·2 1·3	2·2 2·2	1·9 0·8
1102	Boss 6158	H. R. 9074	23 54·4	33 11	6·6	F7	·107	− 2·1	2·6 3·8	3·6 4·0	4·3 4·4

Continued

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1080	2·5	2·3	1·1	1·4	−1·7	1·3	.....	.....	.....	.....	.....	1·0			
	2·0	0·5	1·5	0·4	0·8	2·0	1·4	.....	.....	1·0	.....	1·2	0·5	·019	
1081	−0·6	0·5	.....	0·3	.....	0·6	0·3	1·1	0·8	1·0	.....	0·5			
	0·3	−0·5	−0·5	−0·1	.....	1·9	0·8	−0·3	−0·8	0·4	1·4	0·3	.....	·006	
1082	1·2	3·0	−0·7	2·3	0·2	0·6	1·8	1·8	0·0	0·2	.....	1·2			
	1·3	2·0	−0·6	0·3	0·1	1·8	1·0	−1·0:	0·1	−0·8	.....	0·6	1·5	·013	
1083	5·8	5·4	.....	4·2	5·4	.....	.....	.....	5·6	6·2	.....	5·5			
	5·4	4·6	4·2	3·5	5·0	6·2	6·3	6·0	4·5	5·0	.....	5·2	5·6	·052	·075
1084	.....	.....	.....	−2·2	.....	−0·1	−2·2	−1·7	−0·2	−0·4	−1·7	−1·1			
	.....	.....	.....	−2·3	.....	−1·6	−2·7	−1·1	−1·3	−0·8	−1·2	−1·6	.....	·004	
1085	0·8	1·2	.....	.....	.....	−1·0	1·1	0·4	0·5	.....	.....	0·5:			
	.....	−1·2	−2·5:	−1·0	.....	.....	−0·3	.....	.....	2·4	.....	−0·5:	.....	·005	
1086	.....	.....	2·5	.....	2·1	.....	.....	.....	.....	.....	.....	2·1			
	.....	.....	1·4:	−0·2:	1·8:	.....	.....	.....	.....	.....	.....	1·6	.....	·013	
1087	4·0	3·6	0·1	3·5	2·9	1·1	2·3	2·4	2·4	0·8	.....	2·4			
	3·4	4·2	1·3	2·9	0·3	0·0	2·2	3·6	.....	.....	.....	2·4	2·5	·048	·028
1088	4·6	.....	1·9	4·0	2·6	.....	.....	.....	.....	.....	.....	3·2			
	3·2	.....	3·3	3·0	2·5	.....	.....	.....	.....	.....	.....	3·1	3·9	·059	·098
1089	.....	.....	1·8	.....	1·5	.....	.....	.....	.....	.....	.....	1·9			
	.....	.....	−1·3	1·6	1·4	.....	.....	.....	.....	.....	.....	1·6	.....	·013	
1090	3·0	2·4	4·1	4·6	5·1	.....	2·5	2·8	2·4	1·6	.....	3·1			
	3·8	1·7	4·9	5·0	4·4	2·9:	1·9	3·1	5·0:	2·4	.....	3·4	.....	·093	·070
1091	0·6	3·3	0·7	3·5	0·0	0·9	3·0	2·1	0·2	0·4	.....	1·4			
	1·0	1·9	−0·6	1·7	1·7	1·8	1·4	.....	−0·8	0·6	.....	0·9	1·1	·017	
1092	2·6	.....	1·2	2·5	1·8	1·1	.....	.....	.....	.....	.....	1·2			
	2·0	3·7	1·3	−0·6	2·2	2·4	2·6	.....	.....	0·8	.....	1·6	0·3	·009	
1093	.....	.....	1·7	.....	2·6	.....	.....	.....	.....	.....	.....	2·3			
	.....	.....	−0·3	1·9:	.....	.....	.....	.....	.....	.....	.....	1·7:	.....	·013	
1094	3·5	.....	1·9	3·6	−0·3	.....	.....	.....	.....	.....	.....	2·0			
	4·8	.....	−0·3	0·0	−0·5	.....	.....	.....	.....	.....	.....	1·5	.....	·015	
1095	.....	.....	.....	.....	.....	.....	−2·5	−2·3	−1·7	−1·3	−0·9	−1·7:			
	.....	.....	.....	.....	.....	.....	−1·5	−0·6	−1·3	−0·8	−0·4	−0·9:	.....	·003	
1096	.....	.....	.....	0·7	.....	−0·9	−0·7	−0·7	1·1	0·5	−0·6	−0·2	.....		
	.....	−0·7	−1·1	0·6	.....	−1·0	−1·2	−0·1	−0·2	0·2	0·6	−0·4	0·4	·008	·014
1097	.....	0·0	−4·5	−4·5	−6·0	−1·0	−4·5	−5·0	−4·1	−1·3	.....	−3·7			
	−4·4	0·3	−5·0	−4·4	−6·0	−1·2	−6·0	.....	−4·2	.....	.....	−3·8	−3·3	·002	·032
1098	1·0	2·3	.....	−1·0	2·2	0·1	0·4	1·3	0·0	0·0	.....	0·8			
	1·5	0·9	−1·4	−1·0	1·4	1·8	−0·7	−0·5	−0·8	1·2	.....	0·4	.....	·006	
1099	.....	.....	−0·7	−2·2	−1·4	1·0	1·3	−1·2	−0·9	0·7	.....	−0·8			
	.....	.....	−1·6	−3·6	−1·1	1·4	1·9	0·9	−2·7:	−0·7	.....	−0·8	.....	·004	
1100	.....	.....	0·9	3·5	2·0	.....	.....	.....	.....	.....	.....	2·4			
	.....	.....	3·2	2·6	3·6	.....	.....	.....	.....	.....	.....	3·1	.....	·019	
1101	.....	.....	0·9	1·5	0·4	.....	.....	.....	.....	.....	.....	1·3			
	.....	.....	0·3	0·3	1·0	.....	.....	.....	.....	.....	.....	0·9	2·3	·026	·013
1102	5·5	.....	4·7	5·7	4·5	.....	.....	.....	.....	.....	.....	4·4			
	5·4	.....	3·9	3·2	3·2	3·5	.....	.....	.....	.....	.....	3·9	.....	·032	

TABLE 7—

No.	Star	Name	α (1900)	δ (1900)	Vis. Mag.	Type	μ	Vo	4071 / 77	4215 / 50	4271 / 90
			h m	° ′							
1103	Boss 6158	H. R. 9075	23 54·4	33 11	6·6	F8	·107	+ 0·9	2·6 3·7	4·5 4·5	4·1 4·5
1104	Boss 6172	85 Pegasi A	23 56·8	26 34	5·8	G5	1·295	−29·2	4·7 5·2	5·9 5·2	....
1105	.....	C. 3162	23 59·7	34 06	6·2	G1	·766	+ 9·6	4·8 4·5	3·4 4·4	3·6 3·2

Concluded

No.	4455 62	4455 94	4247 50	4258 60	4162 68	4202 07	4455 82	4455 89	4489 94	4494 96	4482 94	Victoria M	Mt.W. M	Victoria π	Trig. π
1103	2·5	.....	4·9	5·2	3·6	.....	.....	.....	.....	.....	.....	**3·9**			
	3·8	.....	3·0	3·4	3·0	.....	.....	.....	.....	.....	.....	**3·7**	.....	**·028**	
1104	5·9	.....	3·8	6·0	6·1	.....	.....	.....	.....	.....	.....	**5·4**			
	6·0	6·0	.....	3·0	3·4	6·3	4·5	6·6	.....	.....	.....	**5·1**	5·6	**·077**	·096
1105	5·1	.....	1·6	3·6	2·9	.....	.....	.....	.....	.....	.....	**3·6**			
	4·0	.....	3·2	1·2	3·2	.....	.....	.....	.....	.....	.....	**3·4**	4·3	**·029**	·033

NOTES TO TABLE OF RESULTS

Boss 140 $0^h\ 36^m\cdot3$ Star is peculiar, seemingly a blend of A and F-types yet having sharp lines. Results from different pairs of lines are discordant and no absolute magnitude is given.

Boss 179 $0^h\ 44^m\cdot7$ $0^m\cdot5$ has been added to Harvard magnitude on account of the A-type companion.

Boss 307 $1^h\ 17^m\cdot9$ Plates show double lines and $0^m\cdot8$ has been added to Harvard magnitude.

Boss 497 (br) $2^h\ 06^m\cdot6$ The Harvard visual magnitude probably refers to the combined brightness of the close pair. A magnitude $5\cdot5$ corrected by $0\cdot7$ to allow for the spectroscopic component has been adopted.

Boss 497 (ft) $2^h\ 06^m\cdot6$ A magnitude $6\cdot7$ corrected by $0\cdot5$ to allow for faint spectroscopic companion has been adopted.

Boss 694 $2^h\ 57^m\cdot6$ $0^m\cdot5$ has been added to Harvard magnitude to allow for the effect of the A-type component.

Boss 726 $3^h\ 08^m\cdot6$ The spectrum is complex, an F-type spectrum also being present and $0^m\cdot5$ has been added to Harvard magnitude.

Boss 1190 $4^h\ 55^m\cdot5$ This is a spectroscopic binary whose period is between two and three years. The range is a little over 40 km. The B-spectrum so hopelessly mixes up the lines that the absolute magnitude is untrustworthy and no parallax is deduced.

Boss 2602 $9^h\ 35^m\cdot8$ Spectroscopic binary with component spectra about equal in intensity, hence $0\cdot7$ added to visual magnitude. We have tried in this and other cases showing double lines to obtain results for each component. Many difficulties are present, necessitating a more complete treatment of such stars but it would seem that one component in this case is much brighter than the other.

Boss 2632 $9^h\ 43^m\cdot9$ The spectrum has numerous broad fuzzy lines apparently complex and a correction of $0\cdot6$ has been added to visual magnitude.

H.R. 4698 $12^h\ 15^m\cdot7$ **(pr) and (fo)** The Harvard magnitude of $6\cdot30$ must refer to combined brightness though separation large. Addition of $0\cdot7$ to magnitude made but it is questionable.

R.Y. Bootis $14^h\ 45^m\cdot2$ Has previously been listed as a Cepheid. Seems to be an ordinary dwarf F.

Boss 3940 $15^h\ 23^m\cdot7$ Spectroscopic binary and complex spectrum so that $0\cdot5$ has been added to Harvard magnitude.

Boss 4411 $17^h\ 18^m\cdot4$ Spectroscopic binary with component spectra of equal intensity and $0\cdot8$ added to Harvard magnitude.

Boss 4423 $17^h\ 21^m\cdot3$ Spectroscopic binary, spectra quoted of different intensity though masses about equal and $0\cdot7$ has been added to Harvard magnitude.

Boss 5052 $19^h\ 42^m\cdot9$ Composite spectrum and $0\cdot5$ added to Harvard magnitude.

Boss 5200 $20^h\ 12^m\cdot3$ Spectroscopic binary spectrum complex and $0\cdot5$ added to Harvard magnitude.

Boss 5443 $21^h\ 05^m\cdot5$ Plates weak at K-region and type may be earlier than F1.

H.R. 8257 $21^h\ 30^m\cdot9$ Spectroscopic binary with spectra of equal intensity and $0\cdot8$ added to Harvard magnitude.

H.R. 8765 $22^h\ 57^m\cdot8$ Suspect double spectrum and $0\cdot4$ added to Harvard magnitude.

Boss 6033 $23^h\ 22^m\cdot1$ Very poor plates.

Boss 6058 $23^h\ 28^m\cdot5$ Suspect composite though M-type much the stronger.

References

1. Publications, Dominion Astrophysical Observatory, Vol. II, No. 1.
2. Contributions, Mount Wilson Observatory, Volume V, page 67.
3. Contributions, Mount Wilson Observatory, Volume IX, page 423.
4. Transactions of the International Astronomical Union, Volume I, page 95.
5. Monthly Notices, Royal Astronomical Society, Volume LXXXII, page 226.
6. Communications to the National Academy of Sciences, Number 24.
7. Contributions, Mount Wilson Observatory, Number 142.
8. Memoirs of the Royal Astronomical Society, Volume LXII, part IV.

Dominion Astrophysical Observatory,
Victoria, B.C.,
April 15, 1924.

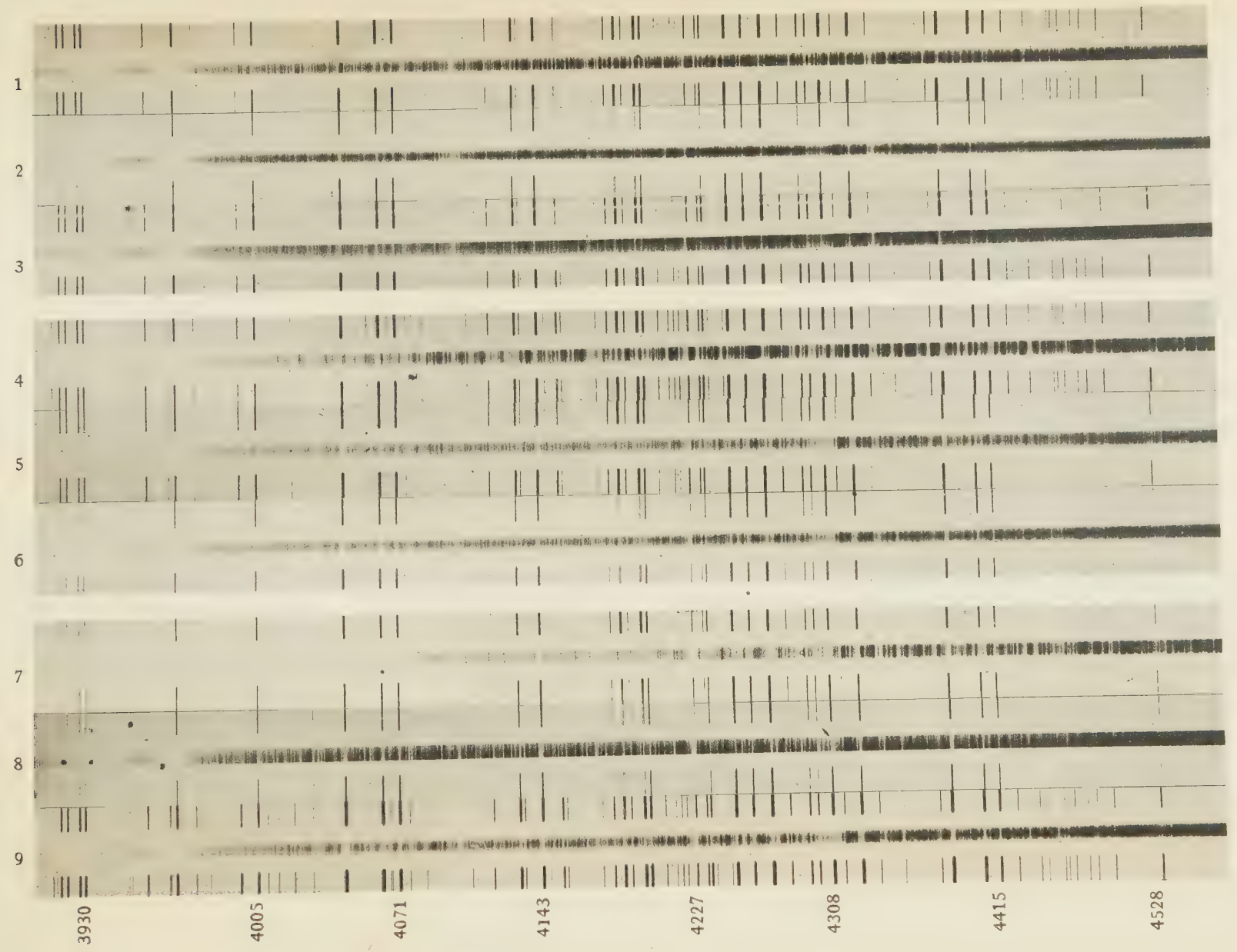


PLATE I.

Single-prism spectra of stars of different absolute magnitude, enlarged about 7.9 times.

1. α Ursæ Minoris, F7, M = −2.2
2. γ Persei, F8, M = +1.0
4. ρ Cassiopeiæ, G6, M = −3.8
5. ϵ Piscium, G6, M = +0.4
7. ξ Cygni, K4, M = −1.5
8. α Bootis, K0, M = +0.2

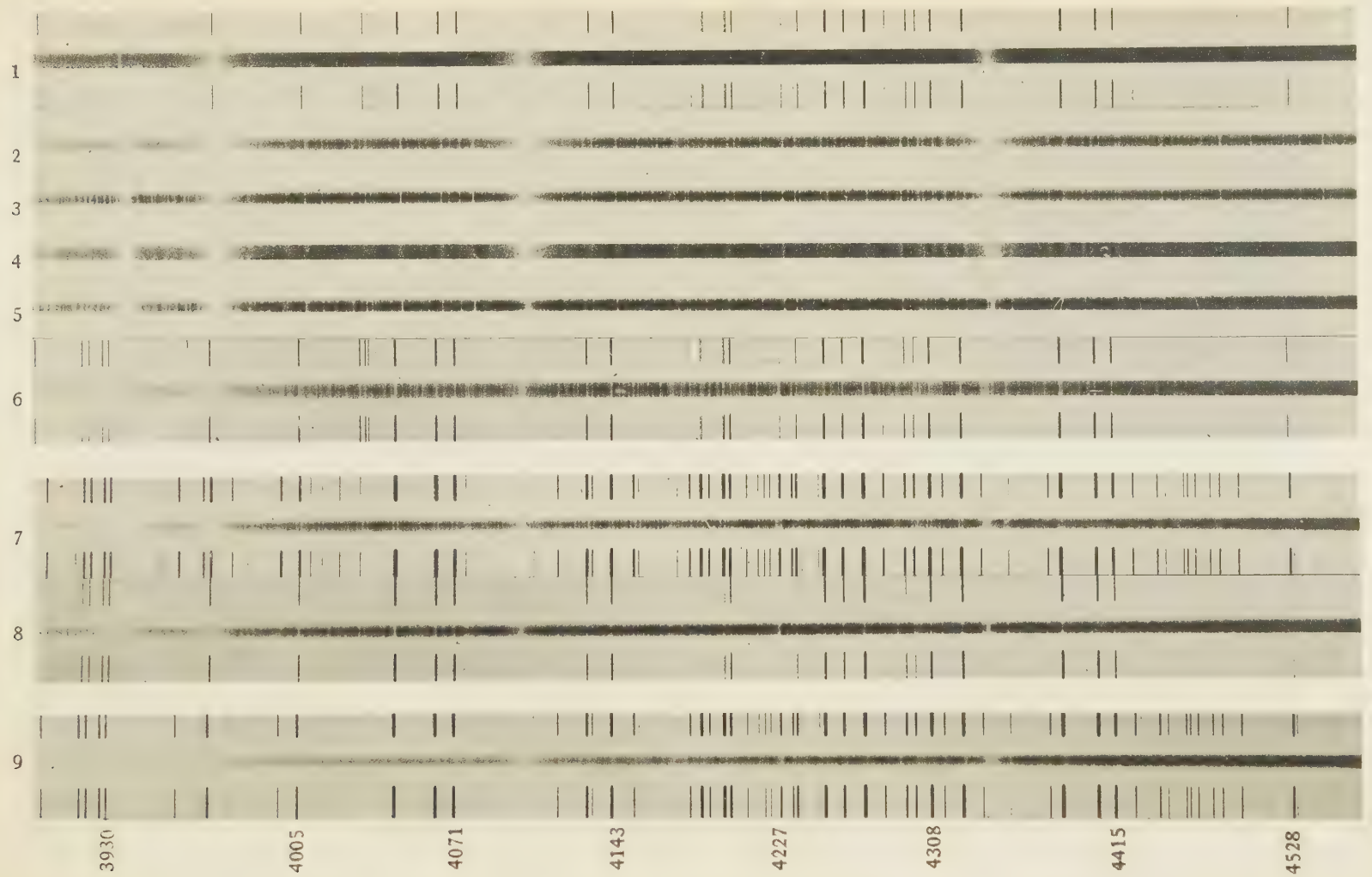


PLATE II.

Numbers 1-6, "early" type spectra, single-prism, enlarged about 7·9 times.

1. α Lyræ, A0
2. 101 Herculis, A3
3. 15 Vulpeculæ, A5
4. τ Bootis, A8
5. γ Herculis, F2
6. γ Serpentis, F7
7. Boss 5026, lines double
8. Boss 5026, lines single
9. Boss 2043, lines fuzzy

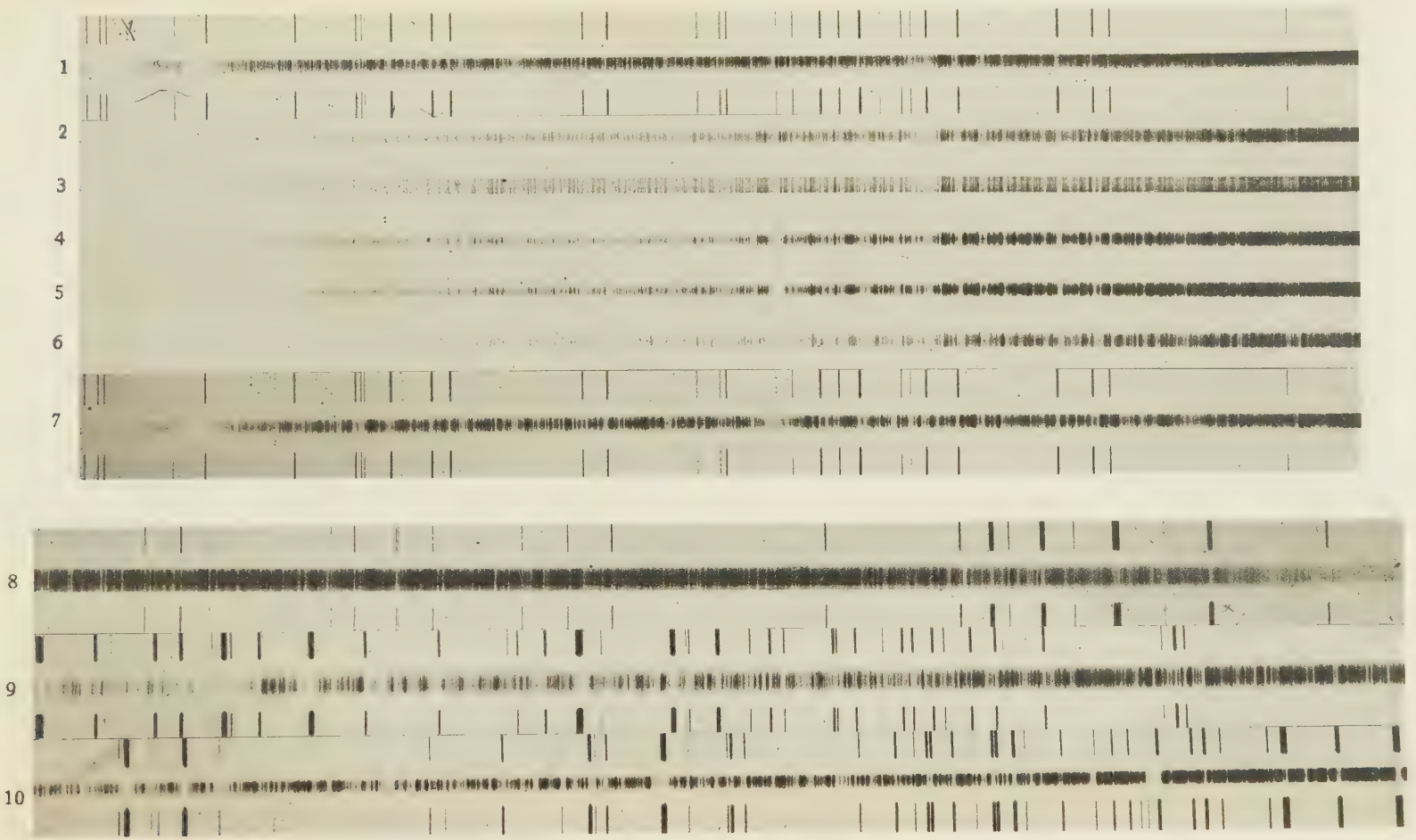


PLATE III.

Numbers 1-7, "late" type spectra, single-prism, enlarged about 7.9 times.

1. ζ Herculis, G1
2. β Bootis, G5
3. α Bootis, K0
4. π Herculis, K3
5. γ Draconis, K5
6. δ Ophiuchi, K9
7. α Herculis, M6
8. α Bootis, III-prism region 5050-4500
9. α Bootis, III-prism region 4600-4270
10. α Bootis, III-prism region 4270-4050

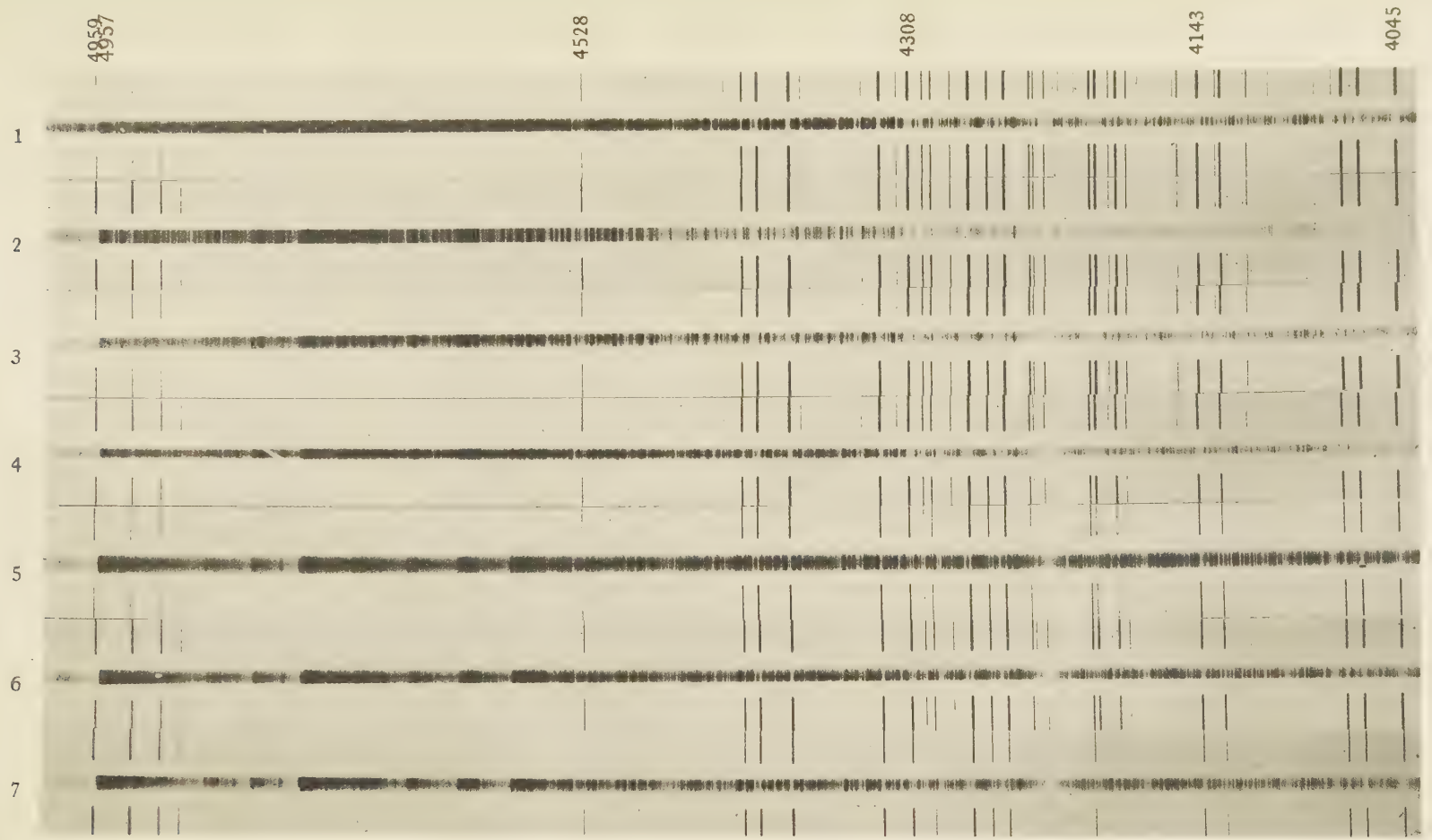


PLATE IV.

Numbers 1-7, M-type spectra, single-prism, enlarged about 6·9 times.

1. β Andromedæ, M0
2. α Orionis, M1
3. η Geminorum, M2
4. Boss 1128, M4
5. α Herculis, M6
6. R Lyræ, M7
7. 45 Arietis, M8
8. Young's scale
9. Harper's scale

PUBLICATIONS

OF THE

Dominion Astrophysical Observatory

VICTORIA

VOL. III, No. 2

THE ORBIT OF THE SPECTROSCOPIC BINARY 5 TAURI

BY W. E. HARPER

ABSTRACT

Twenty-six single-prism spectra of the star 5 Tauri taken during the years 1919 to 1924 are made the basis of the determination of the spectroscopic orbit. The visual magnitude is 4·3 and the type G9, and the probable error of a plate is ±0·9 km/sec. The period is 960 days, eccentricity ·397 and semi-amplitude 8·25 km.

The star 5 Tauri or Boss 804 (1900 $\alpha = 3^h\ 25{\cdot}3^m$, $\delta = +12°\ 36'$), whose visual magnitude is 4·28 and type G9, was announced as a spectroscopic binary by Campbell and Moore in the Astrophysical Journal, Volume 26, page 292, from observations made during the years 1897 to 1907 at the Lick Observatory. Küstner published three velocities also in Astrophysical Journal, Volume 27, page 306, and Adams of Mount Wilson has kindly communicated the results of two others. The writer also obtained eleven velocities of the star at Ottawa in 1917 and 1918. For convenience of reference these are given in the Table of Observations, but apart from serving to determine the period, they have not been made use of. The series at Victoria covers nearly two cycles of the long period of 960 days, and as they have been made and reduced in a uniform manner it is felt that the best results are secured when homogeneous observations are thus made the basis of the determination.

The Victoria plates were made with the single-prism camera attached to the 72-inch reflector, the dispersion at Hγ being 29 angstroms per millimetre. The plates were measured on the spectrocomparator against Arcturus as a standard. The probable error of a plate is ±0·9 km. per second. The Lick three-prism results should be very reliable, and after − 2·0 km. has been added to each to allow for a systematic difference the residuals are all under 1·5 km. They were given most consideration in the determination of the period.

TABLE OF OBSERVATIONS OF 5 TAURI

Observatory	Date	Julian Date	Phase	Velocity	O–C
Lick	1897 Oct. 19	2,414,217·9*	288·3	+15·2	
	" 28	4,226·9	297·3	14·9	
	1898 Oct. 10	4,573·9	624·3	10·7	
	" 17	4,580·9	631·3	12·2	
	" 19	4,582·9	633·3	11·6	
	1903 Nov. 29	6,448·9	599·3	9·	
	1904 Nov. 7	6,791·9	942·3	22·	
	1907 Aug. 5	7,793·9	24·3	27·	
Bonn	1905 Jan. 15	6,861·357	51·8	26·6	
	1907 Jan. 27	7,603·307	793·7	16·4	
	Feb. 1	2,417,608·300	798·7	15·8	
Mt. Wilson	1916 Oct. 8	2,421,145·955	496·4	15·	
	1920 Sept. 2	2,570·978	3·4	22·8	
Victoria—					
2922	1919 Sept. 10	2,422,212·039	602·4	10·3	+1·5
3115	Oct. 3	2,235·972	626·4	9·4	+0·7
3385	Dec. 5	2,298·732	689·1	8·8	−0·1
3501	1920 Jan. 26	2,350·622	741·0	7·8	−1·3
3642	Feb. 20	2,375·607	766·0	10·0	+0·6
3967	May 22	2,406·628	797·0	11·1	+0·8
4954	Aug. 30	2,567·008	957·4	23·6	0·0
5119	Sept. 29	2,597·002	27·4	23·3	−1·7
5157	Oct. 8	2,606·989	37·4	26·9	+1·7
5329	" 29	2,627·795	58·2	25·0	+0·2
5560	Dec. 30	2,689·731	120·1	20·4	−1·2
6537	1921 Sept. 10	2,943·969	374·4	13·7	+1·7
6865	Dec. 3	3,027·670	458·1	10·0	−0·4
6940	" 26	3,050·796	481·2	9·6	−0·4
7186	1922 Feb. 23	3,109·602	540·0	8·8	−0·5
7351	Mar. 25	3,139·643	570·0	6·5	−2·4
8019	Aug. 29	3,295·013	725·4	9·1	+0·1
8294	Nov. 2	3,361·831	792·2	11·2	+1·1
8437	" 27	3,386·790	817·2	12·9	+1·9
8491	1923 Jan. 10	3,430·786	861·2	12·7	−1·0
8499	" 19	3,439·696	870·1	11·8	−2·6
8573	Feb. 24	3,475·657	906·1	20·2	+2·6
8718	Mar. 26	3,505·641	936·0	20·6	−0·5
9313	Aug. 17	3,649·990	120·4	22·0	+0·4
8506	Oct. 8	3,701·961	172·4	19·2	+0·3
9703	1924 Mar. 3	2,423,848·619	318·0	+12·6	−0·8

* The decimal of a day assumed.

The period, as stated above, was 960 days and the phases in the table are reckoned from the periastron passage finally adopted, namely, J.D. 2,414,889·565.

The observations were grouped according to phase into normal places, generally two observations to a place, and preliminary elements determined graphically.

NORMAL PLACES

	Mean Phase		Mean Vel.	Wt.	Residual O-C	
	Prel.	Final			Prel.	Final
1	344·4	346·2	+13·15	2	+1·07	+ ·59
2	467·8	469·6	9·80	2	+ ·10	− ·38
3	538·2	540·0	8·80	1	− ·07	− ·50
4	584·4	586·2	8·40	1	− ·14	− ·51
5	689·4	691·2	8·73	3½	+ ·15	+ ·01
6	783·3	785·1	10·77	3	+ ·45	+ ·67
7	847·7	849·5	12·47	3	−1·07	− ·58
8	922·2	924·0	20·40	2	− ·23	+ ·21
9	955·6	957·4	23·60	1	− ·16	+ ·04
10	30·6	32·4	25·10	2	− ·09	− ·03
11	56·4	58·2	25·00	1	+ ·20	+ ·23
12	118·4	120·2	21·20	2	− ·31	− ·38
13	170·6	172·4	+19·20	1	+ ·70	+ ·48

PRELIMINARY ELEMENTS

$P = 960$ days
$e = \cdot 380$
$\omega = 330°$
$\gamma = +14 \cdot 04$ km.
$K = 8 \cdot 4$ km.
$T = $ J.D. 2,414,891·4

With these preliminary elements a set of observation equations was built up in the usual way and normal equations derived therefrom to obtain corrections to the preliminary values. The observation and normal equations, after the following transformations have been made, are as follows.

$x = \delta\gamma$
$y = \delta K$
$z = K.\delta e$
$u = K.\delta\omega$
$v = 0 \cdot 06947\ \delta T$

OBSERVATION EQUATIONS FOR 5 TAURI

1	1·000x	− ·233y	+ ·168z	+ ·637u	+ ·358v	−1·07 = 0
2	1·000	− ·517	+ ·827	+ ·343	+ ·205	− ·10
3	1·000	− ·615	+ ·983	+ ·139	+ ·130	+ ·07
4	1·000	− ·654	+ ·984	− ·006	+ ·076	+ ·14
5	1·000	− ·649	+ ·584	− ·400	− ·108	− ·15
6	1·000	− ·443	− ·434	− ·826	− ·478	− ·45
7	1·000	− ·059	−1·323	−1·112	−1·013	+1·07
8	1·000	+ ·785	− ·444	−1·080	−1·549	+ ·23
9	1·000	+1·157	+ ·754	− ·751	−1·066	+ ·16
10	1·000	+1·328	+ ·929	− ·241	− ·091	+ ·09
11	1·000	+1·281	+ ·269	+ ·116	+ ·481	− ·20
12	1·000	+ ·890	−1·091	+ ·638	+ ·874	+ ·31
13	1·000	+ ·532	−1·178	+ ·789	+ ·760	− ·70

Normal Equations

24·500x	+2·429y	− ·637z	−6·333u	−4·876v	− ·275 = 0
	13·128	−2·279	− ·029	− ·781	+1·926
		16·897	+3·238	+2·814	−4·107
			11·846	+11·288	−4·507
				12·457	−4·322

From these there resulted small corrections to the elements as follows:

$$\begin{aligned} \delta\gamma &= +\cdot 14 \text{ km.} \\ \delta K &= -\cdot 15 \text{ km.} \\ \delta e &= +\cdot 017 \\ \delta\omega &= -3^\circ\cdot 68 \\ \delta T &= -1\cdot 835 \text{ days} \end{aligned}$$

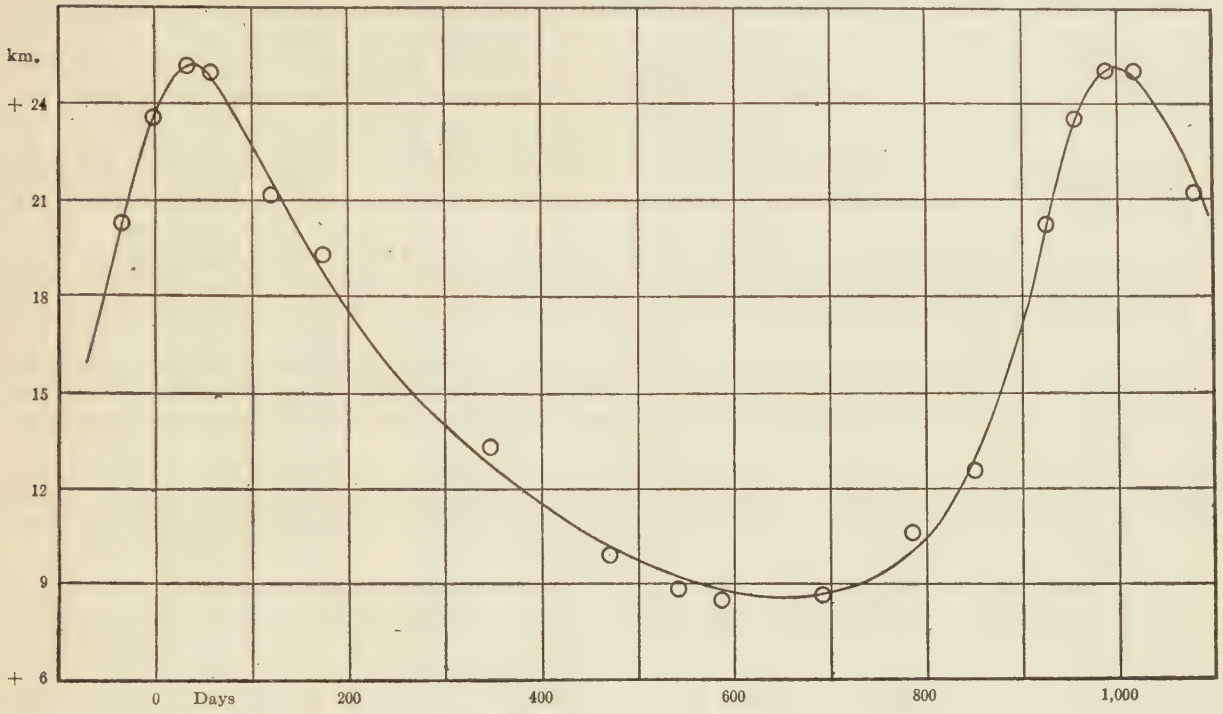
Final Elements

$$\begin{aligned} P &= 960 \text{ days} \\ e &= \cdot 397 \pm 0\cdot 016 \\ \omega &= 326^\circ\cdot 32 \pm 2^\circ\cdot 99 \\ \gamma &= +14\cdot 18 \text{ km.} \pm 0\cdot 11 \text{ km.} \\ K &= 8\cdot 25 \text{ km.} \pm 0\cdot 15 \text{ km.} \\ T &= \text{J.D. } 2{,}414{,}889\cdot 565 \pm 5\cdot 87 \\ a \sin i &= 99{,}955{,}000 \text{ km.} \end{aligned}$$

The sum of the squares of the residuals for the normal places was reduced from 7·32 to 4·47 and satisfactory agreement existed between equation and ephemeris residuals, the differences all being under ·03 km.

In our absolute magnitude work we find a value for this star of +1·5 corresponding to a parallax of ″·028

The accompanying curve represents the final elements and shows the observations as grouped.



Radial Velocity Curve of 5 Tauri.

Dominion Astrophysical Observatory,

Victoria, B.C., June 30, 1924.

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Vol. III, No. 3

THE ORBIT OF THE SPECTROSCOPIC BINARY ZETA AURIGAE

BY W. E. HARPER

ABSTRACT

The star *zeta* Aurigae, $4^h\ 55{\cdot}5^m + 40\ 56'$, has a composite spectrum consisting of one of K-type overlying one of much "earlier" type, giving a "washed out" appearance to the spectrum. On one plate, taken when the main star was nearest the sun, the absorption lines are, however, decidedly more intense than usual. The orbital elements are determined from a series of plates made at Victoria. The period is 973 days, the eccentricity ·411. The probable error of a plate is ±1·0 k.m. per sec.

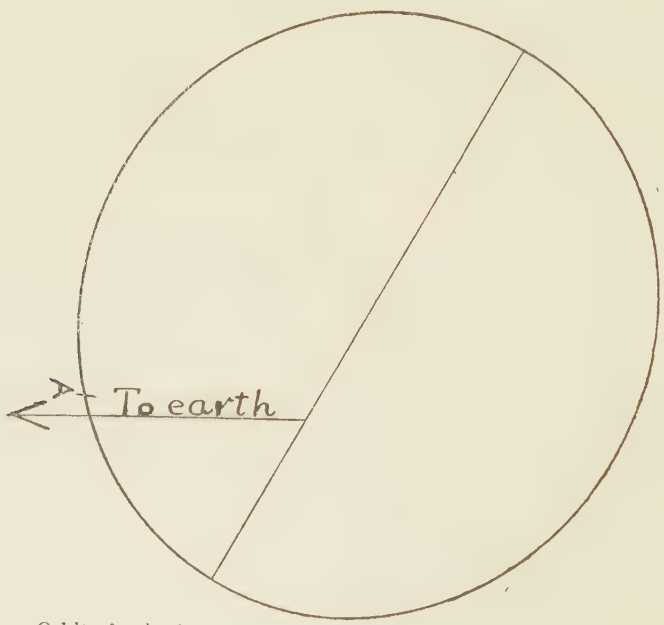
This star (1900 $\alpha = 4^h\ 55^m{\cdot}5$, $\delta = +40°\ 56'$) was announced as a spectroscopic binary by Dr. Campbell, of the Lick Observatory, in December 1908, from seven plates taken during the years 1898 to 1908. The first five plates showed practically a constant velocity, but the sixth and seventh, being about 19 km. different to the others, showed unmistakably that the radial velocity was variable. At Harvard College Observatory Miss Maury had previously classified the spectrum as peculiar, and in view of this feature her description of its spectrum will be given in part. "The star is one of the most beautiful examples of composite spectra found among stars not known to be double. The spectrum predominant in the blue is of Group XV (K-type), agreeing with α Bootis (KO) except in the hydrogen lines Hβ and Hγ, which are far too strong for the group. The spectrum predominant in the violet and ultra-violet appears to be of the Orion type and may probably be classed in Group V (B5). The remaining lines of the hydrogen series from epsilon to nu have the great intensity characteristics of stars of the later Orion type or earlier first type, while that of the line Hδ is but little reduced. The band K appears merely as an inconspicuous haze, or in the best plate as a more distinct but narrow line. In the region having wave length shorter than λ4000, solar lines are few compared with the number found in normal stars of the second type . . . The Orion line λ4026·4 is present."

In general, our spectra, also of one-prism dispersion, agree with this description, though λ3850 is about the limit recorded and nothing definite can be stated regarding the last members of the hydrogen series. The spectrum gives the appearance of a K-type over which is superposed one of nearly a continuous nature and thus has the appearance of being "washed out" or having absorption lines broad and decidedly lacking in contrast. The measures have been made on the spectrocomparator using α Bootis 2702 (K0) as the standard and as the measuring proceeded it was felt that an error of considerable magnitude would be found to exist in the measures as the spectra, from what has just been said, were not exactly matched. However, by taking care to have the magnification equal and using longer stretches of spectrum than usually held in view for each region it was possible to wipe out local regional differences, and it was very

84244

satisfactory to find, when the orbit had been completed, that the probable error of a plate was only $\pm 1 \cdot 0$ km. per sec. While the measures depend upon direct comparison with a standard plate, micrometer measures were also made on several plates, more particularly to see if the helium lines λλ4471 and 4026 were present. A broad line is present at λ4471·6 and measures of it agree in velocity with that of the plate in general. It is very faint and washy and moreover is matched in position by a line in an ordinary K5 spectrum, so that one could not state definitely that it is due to helium. While Miss Maury states that λ4026·4 is present, measures on several plates here fail to confirm this. There are two lines near its position, the one of shorter wave length being quite strong, whilst the other is faint. If either is due to helium λ4026 and they belong to the other spectrum, there should be varying differences of velocity given by them with respect to the K-type spectrum. The difference is found to be constant and values of the wave-lengths of about λ4024·9 and λ4027·0 would cause them to agree quite well with the other lines of the K-type spectrum. These lines again are seen to be present in an ordinary K5 spectrum, so it would seem, then, that the evidence is against the presence of helium λ4026.

But what appears most striking of all in our spectra is the evidence of change. While the "washed-out" appearance is characteristic of nearly all the spectra, yet there is one plate, number 9678, taken at the time when the K-type star is nearest to the sun, which is markedly different to the others in that its absorption lines are particularly intense. The reproduction of this spectrum with one of the least "washed out" of the others will suffice to indicate the decided change. According to the elements here determined the K-type star is nearly, though not quite, in the line of sight. If it were, then the eclipse of the B-type by the K-type would explain the character of the spectrum. The probability in an orbit of the magnitude here determined of such an eclipse is, of course, very small. The graph of the orbit shows the position of the star at A when the K-type absorption lines are of such marked intensity.



Orbit of ζ Aurigae showing position of star 1924 January 18

Observations of the star were made by Kustner at Bonn with a single-prism in 1910, 1911 and 1913, his four plates covering nearly the whole range found in the star. At Mount Wilson also, three plates were made in 1916, 1917 and 1918. The writer started to take spectra of the star, with a view to the determination of its orbit, in 1917, while at Ottawa. Eighteen spectra were secured with the single-prism during 1917, 1918 and January 1919. These were measured on the micrometer engine and it was found somewhat difficult to choose lines giving good internal agreement for the plate. While these results show the general trend of the curve, yet the range is less than found here. Whether this is due to real variation of range at different epochs or whether the lack of complete agreement is due to the less satisfactory system of measurement used in the first case cannot be stated, but in any event it was deemed advisable for the sake of homogeneity to use the Victoria plates exclusively in the orbital determination. For sake of completeness a table of the observations at other observatories is given. The period suggested by the Victoria observations is 975 days. This been changed to 973 days as a compromise for all the observations and is uncertain to the extent of a day or two. The Lick observations might be somewhat improved by a lower value.

MEASURES OF BOSS 1190 AT OTHER OBSERVATORIES

Observatory		Date	Julian Day		Velocity
Lick III		1898 Dec. 4	2,414,628·9		+ 0·1
		1899 Dec. 3	4,992·9		+ 5·0
		1903 Dec. 29	6,478·9		+ 2·5
		1906 Sept. 30	7,484·9		+ 3·2
		1907 Oct. 10	7,859·9		+ 4·
		1908 Sept. 27	8,212·9		+25·
		Oct. 26	2,418,241·9		+20·
Bonn I		1911 Feb. 10	2,419,078·35		+41·0
		Feb. 13	9,081·34		+42·9
		1912 Mar. 9	9,471·27		+ 1·0
		1913 Feb. 20	2,419,819·29		+ 6·3
Mt. Wilson I		1916 Dec. 6	2,421,204·895		+12·0
		1917 April 1	1,320·645		+ 2·6
		1918 Jan. 21	2,421,615·802		− 2·
	Plate Number			Lines	
Ottawa	8286	1917 Sept. 6	2,421,478·805	16	+ 8·8
	8315	Oct. 1	1,503·736	11	+ 5·8
	8320	" 9	1,511·721	15	+ 1·3
	8330	" 30	1,532·722	20	− 2·0
	8349	Nov. 12	1,545·691	16	+ 6·9
	8361	" 24	1,557·684	12	+ 7·7
	8374	Dec. 5	1,568·640	11	+ 7·5:
	8384	" 15	1,578·468	9	+ 3·4:
	8391	" 26	1,589·564	12	+ 3·5
	8420	1918 Jan. 12	1,606·541	16	+ 7·4
	8435	" 29	1,623·488	18	+ 5·2
	8452	Feb. 20	1,645·540	15	+ 3·5
	8675	Nov. 1	1,899·660	17	+28·9
	8685	" 27	1,925·645	18	+42·7
	8687	Dec. 6	1,934·714	12	+37·3
	8697	" 26	1,954·714	16	+36·5
	8700	1919 Jan. 21	1,980·621	8	+44·4
	8707	" 27	2,421,986·475	15	+32·4

VICTORIA MEASURES OF BOSS 1190

Plate	Date	Julian Day	Phase	Velocity	Regions	Wt.	O–C
3049	1919 Sept. 22	2,422,224·024	290·55	+ 9·6	1–23	1	−0·1
3156	Oct. 7	2,239·025	305·55	+ 7·8	5–23	1	−0·6
3387	Dec. 5	2,298·787	365·42	+ 4·2	5–23	½	−1·0
3469	1920 Jan. 19	2,343·709	410·24	+ 0·8:	11–23	½	−0·9
3554	Feb. 9	2,364·593	431·12	− 2·9	1–23	1	−3·6
3911	Mar. 15	2,399·619	466·15	+ 0·9	5–23	1	+1·4
4073	April 12	2,427·652	494·18	− 1·4	5–23	1	−0·1
4955	Aug. 30	2,567·024	633·55	− 3·0	9–23	1	+1·2
5342	Oct. 29	2,627·888	694·42	− 6·2	5–23	1	−1·9
5632	1921 Feb. 3	2,724·714	791·24	− 1·8	1–23	1	−1·1
6538	Sept. 10	2,943·990	37·52	+43·5	1–23	1	+0·6
6630	" 30	2,963·973	57·50	+39·6	5–23	1	−1·7
6868	Dec. 3	3,027·848	121·38	+31·7	5–23	1	+1·0
6944	" 26	3,050·773	144·30	+29·1	5–23	½	+2·6
7075	1922 Jan. 28	3,083·579	177·11	+24·5	10=23	½	+3·0
7187	Feb. 23	3,109·614	203·14	+19·7	1–23	1	+1·3
7188	" 23	3,109·627	203·16	+18·5	1–23	1	+0·1
7352	Mar. 25	3,139·660	233·19	+13·9	3–23	1	−1·1
7488	April 22	3,167·660	261·19	+ 9·2	5–23	1	−2·8
8018	Aug. 28	3,295·994	389·52	+ 4·6	9–23	1	+1·8
8492	1923 Jan. 10	3,430·760	524·29	− 1·2	5–23	1	+0·9
8599	Feb. 26	3,477·686	571·22	− 2·9	5–23	1	+0·3
9545	Oct. 22	3,715·981	809·51	+ 1·9	1–23	1	+1·0
9649	Dec. 7	3,761·864	855·39	+ 7·7	1–23	1	0·0
9678	1924 Jan. 18	3,803·690	897·22	+16·7	1–23	1	−0·6
9705	Mar. 3	3,848·656	942·19	+32·4	1–23	1	+1·0
9827	April 7	3,883·653	4·18	+43·8	7–23	½	+3·0
9836	" 14	2,423,890·668	11·20	+39·6	1–23	1	−2·0

NORMAL PLACES

—	Mean Phase		Velocity	Wt.	Residual O–C	
	Prel.	Final			Prel.	Final
1	543·56	547·75	− 2·05	2	+1·49	+1·17
2	659·80	663·99	− 4·60	2	+0·36	−0·04
3	796·18	800·37	+ 0·05	2	−0·04	−0·48
4	851·20	855·39	+ 7·70	1	+0·53	−0·03
5	893·03	897·22	+16·70	1	+0·24	−0·58
6	938·00	942·19	+32·40	1	+2·13	+0·96
7	4·67	8·86	+41·00	1½	+0·36	−0·37
8	33·33	37·52	+43·50	1	+0·50	+0·61
9	53·31	57·50	+39·60	1	−2·35	−1·71
10	117·19	121·38	+31·70	1	−0·28	+0·96
11	156·52	160·71	+26·80	1	+1·43	+2·53
12	198·96	203·15	+19·10	2	−0·19	+0·67
13	243·00	247·19	+11·55	2	−2·55	−1·96
14	293·86	298·15	+ 8·70	2	−0·91	−0·46
15	384·46	388·65	+ 3·55	2	+0·60	+0·63
16	459·63	463·82	− 1·13	3	−0·39	−0·56

Using the value of the period the observations were grouped according to phase into 16 normal places and preliminary elements graphically determined as follows:

$$\begin{aligned} P &= 973 \text{ days} \\ e &= \cdot 40 \\ \omega &= 330^\circ \\ K &= 24 \cdot 0 \text{ km.} \\ \gamma &= +10 \cdot 69 \text{ km.} \\ T &= \text{J.D. } 2{,}415{,}126 \cdot 66 \end{aligned}$$

With these there were built up sixteen observation equations connecting the five elements e, ω, K, γ and T with the residuals. The weights for each equation are those given in the corresponding number for the normal places. For the sake of homogeneity the following transformations were made.

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K \\ z &= K.\delta e \\ u &= K.\delta \omega \\ v &= 0 \cdot 20131 \, \delta T \end{aligned}$$

OBSERVATION EQUATIONS FOR BOSS 1190

1	1·000x	− ·593y	+ ·980z	+ ·143u	+ ·130v	−1·490 = 0
2	1·000	− ·653	+ ·830	− ·234	− ·015	− ·360
3	1·000	− ·442	− ·390	− ·815	− ·444	+ ·040
4	1·000	− ·147	−1·208	−1·070	− ·875	− ·530
5	1·000	+ ·241	−1·474	−1·194	−1·340	− ·240
6	1·000	+ ·816	− ·435	−1·083	−1·583	−2·130
7	1·000	+1·248	+ ·961	− ·632	− ·846	− ·360
8	1·000	+1·346	+ ·852	− ·190	+ ·017	− ·500
9	1·000	+1·303	+ ·287	+ ·093	+ ·474	+2·350
10	1·000	+ ·887	−1·153	+ ·641	+ ·873	+ ·280
11	1·000	+ ·612	−1·244	+ ·764	+ ·779	−1·430
12	1·000	+ ·359	−1·007	+ ·800	+ ·646	+ ·190
13	1·000	+ ·142	− ·641	+ ·779	+ ·526	+2·550
14	1·000	− ·049	− ·233	+ ·719	+ ·425	+ ·910
15	1·000	− ·322	+ ·422	+ ·544	+ ·286	− ·600
16	1·000	− ·476	− ·012	+ ·369	+ ·205	+ ·390

The following normal equations resulted:

$$\begin{aligned} 25 \cdot 500x + 2 \cdot 386y - 3 \cdot 048z + 1 \cdot 992u + \cdot 799v + \cdot 910 &= 0 \\ 10 \cdot 890 - 2 \cdot 034 - \cdot 592 - \cdot 825 + 2 \cdot 172 &= 0 \\ 15 \cdot 809 - 1 \cdot 182 - \cdot 688 - 5 \cdot 039 &= 0 \\ 11 \cdot 390 + 10 \cdot 019 + 7 \cdot 944 &= 0 \\ 10 \cdot 203 + 8 \cdot 038 &= 0 \end{aligned}$$

These gave corrections as follow:

$$\begin{aligned} \delta\gamma &= +0{\cdot}04 \text{ km.} \\ \delta K &= -0{\cdot}22 \text{ km.} \\ \delta e &= +0{\cdot}011 \\ \delta\omega &= +0^\circ{\cdot}13 \\ \delta T &= -4{\cdot}189 \text{ days} \end{aligned}$$

and one solution gave satisfactory agreement between equation and ephemeris residuals, none exceeding 0·1 km. The sum of the squares of the residuals for the normal places was reduced from 33·5 to 26·0.

The final values, then, of the elements, with their probable errors are the following:

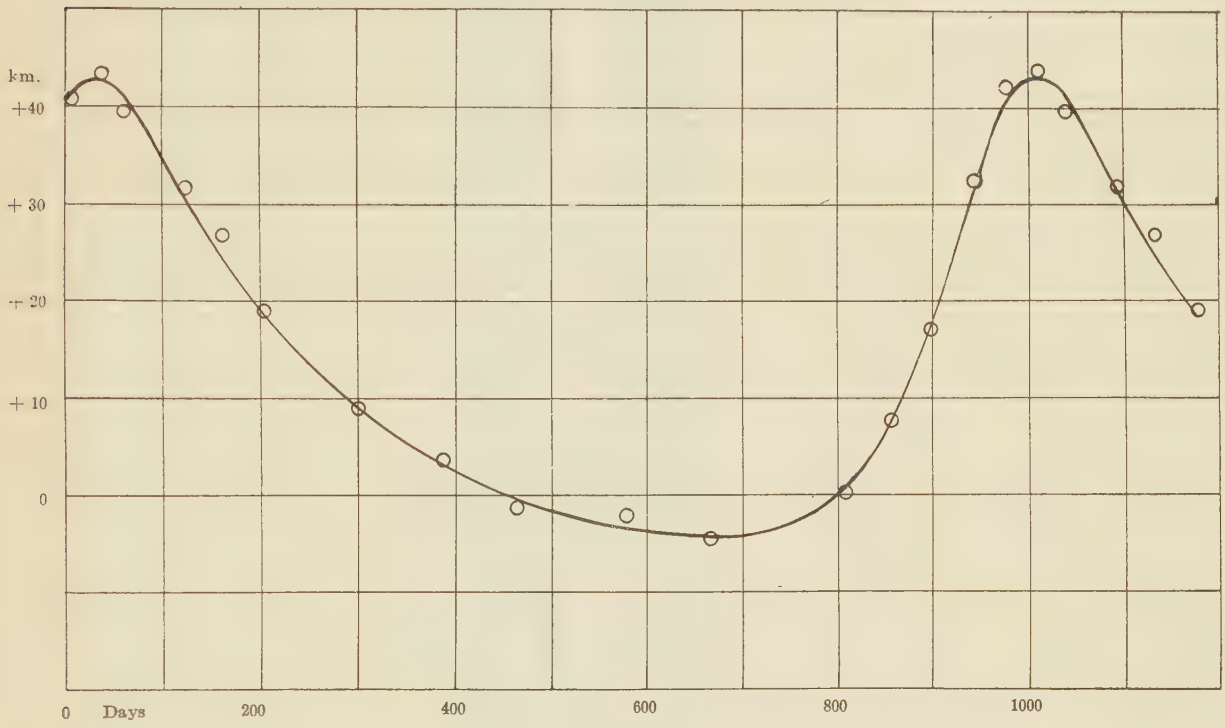
$$\begin{aligned} P &= 973 \text{ days} \\ e &= {\cdot}411 \pm {\cdot}011 \\ \omega &= 330^\circ{\cdot}13 \pm 2^\circ{\cdot}04 \\ \gamma &= +10{\cdot}73 \text{ km.} \pm 0{\cdot}21 \text{ km.} \\ K &= 23{\cdot}78 \text{ km.} \pm 0{\cdot}32 \text{ km.} \\ T &= \text{J.D. } 2{,}415{,}122{\cdot}471 \pm 4{\cdot}454 \text{ days} \\ a \sin i &= 294{,}300{,}000 \text{ km.} \end{aligned}$$

While the elements above are spoken of as final, it is only in the sense of their being the best for the Victoria observations. It is intended to continue observations here in succeeding years to see what changes occur. A trial was made with the three-prism instrument when the star was at the peak of the curve to see if the second spectrum, if any, could be separated from the main one, but the star had got so far west that the plate was not a success. Such three-prism spectra might well repay a detailed study. The explanation of the complex spectrum might be ascribed to a physical double, and in that case interferometer measures in the early autumn of 1925, when the star is at apastron, would be worth while. If binary, the separation then would be in the neighbourhood of ·07 second of arc.

In the list of 1105 spectroscopic parallaxes, Volume III, No. 1 of our *Publications*, no parallax is deduced from the absolute magnitude derived. Since then, in reviewing the plates, it has seemed that plate No. 9678, here reproduced, was worthy of being used in that connection. The absolute magnitude from about ten pairs of lines considering its type about K5, which it seems to be, would be −0·5 corresponding to a parallax of ″·013.

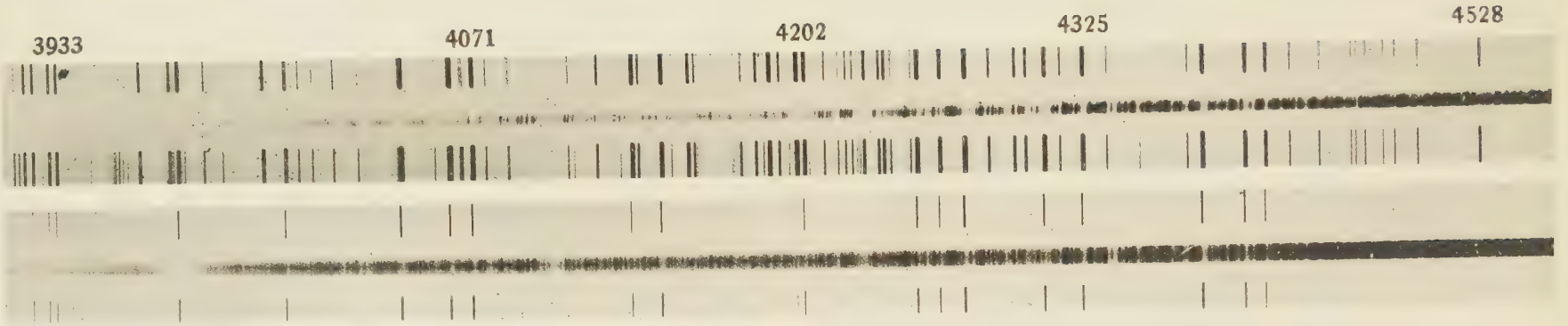
The value of the mass function from the final elements is 1·03 times the sun. Assuming 0·65 as the most probable value for the unknown $\sin^3 i$ in that function, and further assuming that the masses of the components are equal, we have a total mass of the system of 12·7 times that of the sun. If the spectrum which is mixed with the K-type belongs to the other member of the physical system, then, being of "earlier" type, its mass will be greater and the total mass of the system will be correspondingly increased.

The graph shows the final elements with the Victoria observations as grouped. The probable error of a plate is $\pm 1 \cdot 0$ km. per sec. The Lick and Bonn results give positive residuals, while Mount Wilson are slightly negative.



Velocity Curve of Zeta Aurigae

Dominion Astrophysical Observatory,
Victoria, B.C.,
June 2, 1924.



Spectral Changes in ζ Aurigæ

Upper—1924 Jan. 18 showing strong absorption lines.

Lower—1922 Feb. 23 showing usual "washed out" appearance.

PUBLICATIONS

OF THE

Dominion Astrophysical Observatory

VICTORIA

VOL. III, No. 4

THE ORBIT OF THE SPECTROSCOPIC BINARY BOSS 1452

BY W. E. HARPER

ABSTRACT

Twenty-five spectrograms of the star Boss 1452 with single-prism dispersion are made the basis of a determination of the orbital elements. The measures depend for the most part on four lines, and the probable error of a plate is ±3·1 km. per sec. The period is 2·93317 days, and eccentricity ·030.

The star Boss 1452 (1900 $\alpha = 5^h\,46{\cdot}0^m$, $\delta = +59°\,52'$, visual magnitude 5·26, type A1) was announced as a spectroscopic binary in the first list of 100 spectroscopic binaries issued from this observatory, Volume I, page 168. The spectrum contains fairly well defined lines of hydrogen, the calcium K, the magnesium 4481 and numerous metallic lines all of which are too faint and elusive to measure except λ4549 and occasionally λ4233. The results, then, rest for the most part upon the four lines λλ4481, 4340, 4101 and 3933. The probable error of a plate as based upon the residuals from the curve representing the final elements is ±3·1 km. per sec.

The period determined from the 1922 and 1923 observations taken in conjunction with the six obtained by Dr. J. S. Plaskett in 1918 and 1919 is 2·9331 days. The table of observations, normal places and preliminary elements follow:

OBSERVATIONS OF BOSS 1452

Plate Number	Date	Julian Date	Phase	Velocity	Lines	Residual O–C
1025	1918 Dec. 10	2·421,938·924	0·604	+21·0		+ 5·0
1120	" 21	1,949·892	2·773	+67·8		− 1·2
1364	1919 Feb. 1	1,991·758	0·641	+ 6·2		− 3·7
1378	" 2	1,992·683	1·566	−76·4		− 0·1
1425	" 11	2,001·751	1·834	−60·1		− 2·4
1426	" 11	2,001·759	1·842	−51·9		+ 5·8
8302	1922 Nov. 2	3,361·980	1·073	−62·9	5	− 9·1
8346	" 11	3,370·907	1·200	−62·5	4	+ 3·8
8441	" 27	3,386·878	2·505	+31·8	4	− 8·9
8502	1923 Jan. 19	3,439·788	2·618	+66·9	1	+11·7
8535	" 28	3,448·755	2·786	+74·0	7	+ 3·9
8540	" 31	3,451·718	2·815	+70·5	4	− 0·7
8602	Feb. 26	3,477·743	2·442	+32·0	6	+ 0·4
8635	Mar. 2	3,481·728	0·561	+26·7	5	+ 4·1
8665	" 16	3,495·740	2·840	+75·5	5	+ 2·8
8678	" 19	3,498·721	2·888	+69·4	5	− 4·6
8699	" 24	3,503·656	1·956	−39·1	5	+ 4·7
8721	" 26	3,505·710	1·077	−57·1	4	− 2·8
8760	" 30	3,509·657	2·091	−26·5	6	− 2·2
8761	" 30	3,509·698	2·132	−15·3	6	+ 3·0
8774	April 2	3,512·639	2·140	−15·0	5	+ 1·9
8806	" 9	3,519·694	0·395	+52·7	4	+ 6·4
8807	" 9	3,519·705	0·406	+47·5	5	+ 1·6
8862	" 23	3,533·673	2·642	+54·7	6	− 3·1
8895	" 27	2,423,537·697	0·799	−20·7	8	− 5·0

NORMAL PLACES

	Mean Phase		Velocity	Wt.	O–C			Mean Phase		Velocity	Wt.	O–C	
	Prel.	Final			Prel.	Final		Prel.	Final			Prel.	Final
1	2·618	2·618	+66·9	0·2	+11·6	+11·7	11	1·198	1·200	−62·5	1·0	+2·5	+3·8
2	2·737	2·773	+67·8	1·0	+ 0·8	− 1·2	12	1·531	1·566	−76·4	1·0	−2·0	−0·1
3	2·801	2·800	+72·2	2·0	+ 0·8	+ 1·6	13	1·804	1·838	−56·0	2·0	+3·2	+1·7
4	2·865	2·864	+72·4	2·0	− 1·6	− 0·9	14	1·958	1·956	−39·1	1·0	+3·3	+4·7
5	·402	·401	+50·1	2·0	+ 5·8	+ 4·0	15	2·114	2·112	−20·9	2·0	−0·1	+0·4
6	·561	·561	+26·7	1·0	+ 6·5	+ 4·1	16	2·141	2·140	−15·0	1·0	+1·6	+1·9
7	·568	·604	+21·0	1·0	+ 1·9	+ 5·0	17	2·443	2·442	+32·0	0·5	+0·6	+0·4
8	·606	·641	+ 6·2	1·0	− 6·8	− 3·7	18	2·504	2·505	+31·8	1·0	−8·6	−8·9
9	1·071	1·073	−62·9	1·0	− 9·3	− 9·1	19	2·644	2·642	+54·7	1·0	−3·6	−3·1
10	1·079	1·077	−57·1	1·0	− 2·7	− 2·8	20	·802	·799	−20·7	1·0	−2·5	−5·0

Preliminary Elements

$P = 2{\cdot}9331$ days
$e = {\cdot}05$
$\omega = 0°$
$\gamma = -3{\cdot}75$ km.
$K = 75$ km.
$T = $ J.D. 2,421,938·356

Using these values as preliminary a set of twenty observation equations weighted as above was built up according to the Lehmann-Filhés method connecting the residuals with the six elements of the orbit. The different years were kept separate, since the period was included in the solution. For the sake of homogeneity the following transformations were made.

$x = \delta\gamma$
$y = \delta K$
$z = K.\delta e$
$u = -K.\delta\omega$
$v = -[4{\cdot}87607]\ \delta\mu$
$w = [2{\cdot}20756]\ \delta T$

OBSERVATION EQUATIONS FOR BOSS 1452

1	1·000x	+ ·787y	+ ·067z	− ·676u	+ ·000v	− ·727w	− 11·6=0
2	1·000	+ ·944	− ·588	− ·448	+ ·729	− ·489	− 0·8
3	1·000	+1·002	+ ·806	− ·307	− ·003	− ·337	− 0·8
4	1·000	+1·037	+ ·947	− ·162	− ·010	− ·178	+ 1·6
5	1·000	+ ·641	− ·325	+ ·807	+ ·069	+ ·856	− 5·8
6	1·000	+ ·319	− ·871	+ ·963	+ ·042	+ ·988	− 6·5
7	1·000	+ ·305	− ·887	+ ·967	−1·489	+ ·992	− 1·9
8	1·000	+ ·224	− ·954	+ ·985	−1·452	+1·003	+ 6·8
9	1·000	− ·664	+ ·036	+ ·700	− ·051	+ ·650	+ 9·3
10	1·000	− ·675	+ ·069	+ ·688	+ ·042	+ ·639	+ 2·7
11	1·000	− ·816	+ ·510	+ ·500	− ·032	+ ·458	− 2·5
12	1·000	− ·942	+ ·969	− ·125	+ ·164	− ·113	+ 2·0
13	1·000	− ·740	+ ·261	− ·613	+ ·812	− ·565	− 3·2
14	1·000	− ·516	− ·342	− ·824	− ·050	− ·779	− 3·3
15	1·000	− ·227	− ·840	− ·961	− ·065	− ·934	+ 0·1
16	1·000	− ·172	− ·897	− ·975	− ·070	− ·954	− 1·6
17	1·000	+ ·468	− ·670	− ·908	− ·036	− ·946	− 0·6
18	1·000	+ ·589	− ·441	− ·842	+ ·047	− ·887	+ 8·6
19	1·000	+ ·827	+ ·190	− ·629	− ·064	− ·679	+ 3·6
20	1·000	− ·192	− ·876	+ ·970	+ ·093	+ ·947	+ 2·5

Owing to the small value of the eccentricity and the consequent similarity of the coefficients of u and w (corresponding to ω and T) it was necessary to consider T as fixed and to solve for the remaining elements. The normal equations were

23·700x	+3·048y	−1·530z	−1·131u	− ·503v	+ ·080	= 0
	11·363	+1·800	− ·319	−1·323	−3·177	
		11·003	−1·873	+3·684	+2·560	
			12·581	−3·738	− ·795	
				6·251	−13·197	

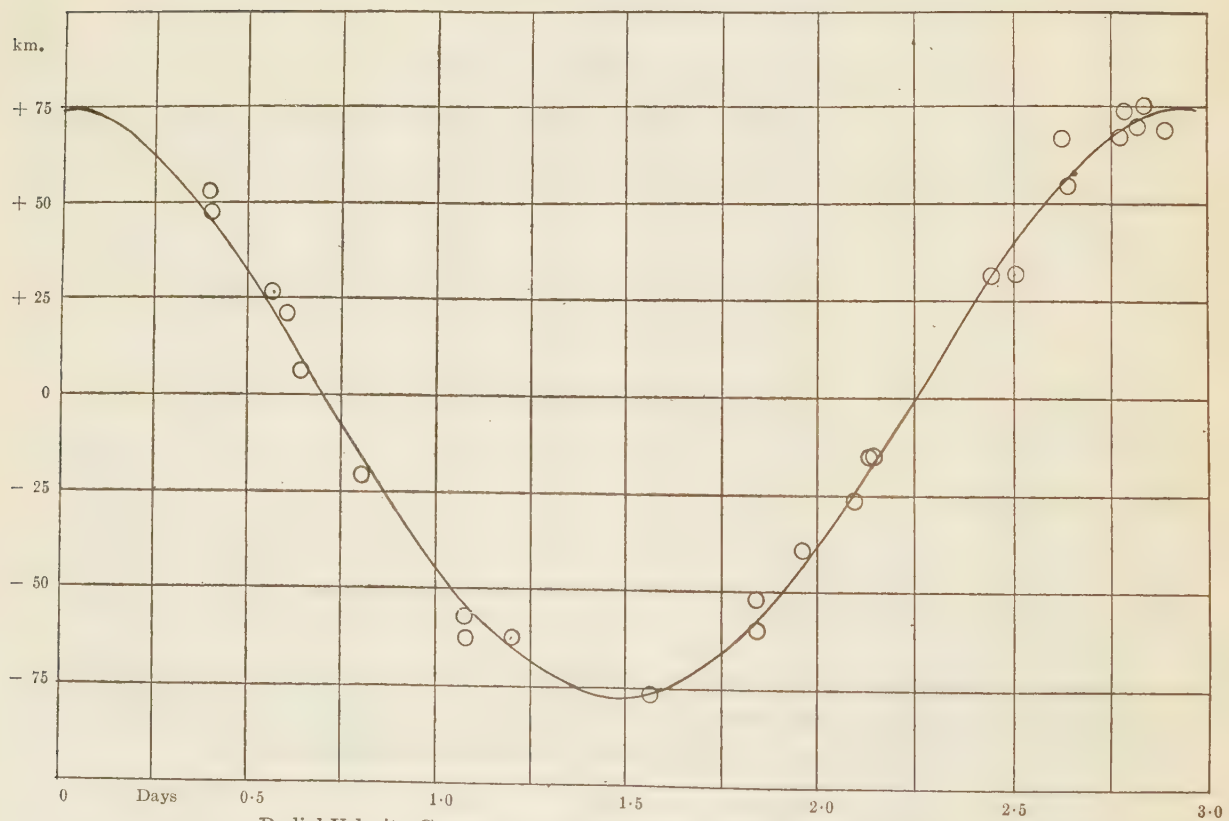
From these there resulted the following corrections:

$$\delta\gamma = -0{\cdot}11 \text{ km.}$$
$$\delta K = +1{\cdot}02 \text{ km.}$$
$$\delta e = -\ {\cdot}020$$
$$\delta\omega = -0°{\cdot}75$$
$$\delta P = +{\cdot}00007 \text{ days.}$$

The sum of the squares of the normal places was reduced about 12 per cent, dropping from 424·4 to 373·7. The final elements, with their probable errors, are given below, and a curve representing them and showing the individual observations accompanies the article.

Final Elements

$$P = 2{\cdot}93317 \text{ days} \pm {\cdot}00003 \text{ days}$$
$$e = {\cdot}030 \pm {\cdot}016$$
$$\omega = 359°{\cdot}25 \pm 0°{\cdot}81$$
$$\gamma = -3{\cdot}86 \text{ km.} \pm 0{\cdot}71 \text{ km.}$$
$$K = 76{\cdot}02 \text{ km.} \pm 1{\cdot}08 \text{ km.}$$
$$T = \text{J.D. } 2{,}421{,}938{\cdot}356$$
$$a \sin i = 3{,}064{,}800 \text{ km.}$$



Radial Velocity Curve of Boss 1452 Showing Individual Observations.

Dominion Astrophysical Observatory,
Victoria, B.C.
July 7, 1924.

PUBLICATIONS

OF THE

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VICTORIA

Vol. III, No. 5

ORBIT OF THE SPECTROSCOPIC BINARY BOSS 6070 AND THE RADIAL VELOCITIES OF FIFTEEN STARS

BY STANLEY SMITH

I. Orbit of the Spectroscopic Binary Boss 6070

The star Boss 6070 or H.R. 8960 (1900 $\alpha = 23^h\ 32{\cdot}6^m$ $\delta = +16°\ 17'$, visual magnitude 6·2, type Ao) was announced to be a spectroscopic binary by Dr. J. S. Plaskett in the Publications of the Dominion Astrophysical Observatory, Vol. I, No. 10, 1920. The determination of the orbit of this star was undertaken by the writer as part of his programme at the Dominion Astrophysical Observatory during the months of June, July and August in 1924. With the kind co-operation of the Observatory staff thirty-four plates were obtained during this period. These together with the original four plates secured by Dr. Plaskett in 1918 led to the conclusion that the period was either 11·2298 days or 11·2922 days. In order to choose between these two possible values of the period Mr. Harper kindly secured in October and December, 1924, some further plates which were measured at the University of Alberta on a comparator employing a Hilger Michelson Interferometer screw of pitch 1 mm. These plates decided in favour of the shorter period. The solution of the orbit is based on the observations from forty-one plates including the four plates of 1918. In the case of the latter the means of Dr. Plaskett's and the writer's measures were used.

The following is the table of observations in which the phases are those given by the corrected period and periastron passage.

OBSERVATIONS OF BOSS 6070

Plate Number	Date	Julian Date	Phase	Number of Lines	Weight	Velocity	O-C
945	1918 Nov. 24	2,421,922·665	5·722	10	2	−11·2	+3·2
993	" 30	928·610	·437	8	2	−33·9	+2·5
1045	Dec. 15	943·623	4·220	14	2	− 2·2	0
1137	" 29	957·624	6·992	10	2	−31·4	+0·1
10141	1924 June 22	2,423,959·948	10·417	14	2	−50·6	+0·8
10151	" 23	960·956	·195	9	2	−38·9	+1·1
10162	" 25	962·935	2·174	15	2	− 9·9	+0·9
10176	" 28	965·948	5·187	13	1	− 4·2	+4·4
10220	July 3	970·929	10·168	17	1	−55·5	−2·4
10236	" 6	973·940	1·949	18	2	−12·8	+0·7
10249	" 7	974·933	2·942	18	2	− 3·1	+0·6
10258	" 8	975·930	3·939	17	2	− 2·1	−0·7
10276	" 11	978·929	6·938	19	2	−30·9	−0·2
10293	" 13	980·917	8·926	22	2	−54·7	−2·0
10307	" 15	982·960	10·969	25	2	−47·0	−1·0
10313	" 17	984·935	1·714	22	2	−15·8	+0·9
10327	" 20	987·919	4·698	19	2	− 8·7	−4·2
10333	" 21	988·927	5·706	21	2	−16·8	−2·6
10347	" 23	990·909	7·688	25	2	−39·9	+1·0
10354	" 24	991·952	8·731	23	2	−48·6	+2·9
10399	" 30	997·898	3·448	24	2	− 2·1	−0·6
10425	Aug. 2	2,424,000·833	6·383	18	2	−22·7	+0·2
10431	" 3	001·875	7·425	23	2	−40·2	−2·8
10439	" 4	002·887	8·437	22	2	−50·2	−1·1
10446	" 5	003·849	9·399	26	2	−53·6	+0·8
10451	" 5	003·983	9·533	26	2	−55·4	−0·8
10455	" 6	004·930	10·480	20	2	−52·6	−1·7
10459	" 7	005·853	0·173	24	2	−40·2	+0·1
10470	" 9	007·865	2·185	25	2	−13·9	−3·3
10477	" 10	008·858	3·178	22	2	− 0·6	+1·9
10488	" 11	009·853	4·173	17	2	− 0·3	+1·6
10503	" 12	010·815	5·135	12	2	− 8·5	−0·4
10508	" 12	010·981	5·301	12	2	−13·8	−4·1
10520	" 20	018·984	2·074	19	2	−13·0	−1·1
10545	" 26	024·903	7·993	23	2	−43·5	+1·1
10553	" 27	025·855	8·945	20	2	−51·4	+1·4
10574	" 30	028·882	0·742	21	2	−32·3	−0·5
10587	" 31	029·829	1·689	13	1	−20·6	−3·6
10913	Oct. 31	090·772	6·483	15	1	−26·1	−1·7
11082	Dec. 22	142·711	2·274	7	1	− 6·3	+3·3
11093	" 23	2,424,143·669	3·232	16	1	− 3·7	−1·5

In forming the normal places twelve pairs of observations were grouped. Of these, two pairs differed by four cycles each, two pairs by three cycles, two pairs by two cycles, five pairs by one cycle and one pair was taken on the same night.

NORMAL PLACES

	Mean Phase		Mean Velocity	Weight	O-C	
	Prel.	Final			Prel.	Final
1	0·291	0·437	−33·9	2	+3·9	+2·5
2	0·553	0·742	−32·3	2	+1·2	−0·5
3	1·500	1·689	−20·6	1	−2·6	−3·6
4	1·644	1·832	−14·3	3	+1·5	+0·7
5	1·941	2·130	−13·5	3	−1·7	−2·3
6	1·986	2·174	− 9·9	2	+1·3	+0·9
7	2·082	2·274	− 6·3	1	+3·8	+3·3
8	2·754	2·942	− 3·1	2	+0·7	+0·6
9	3·040	3·232	− 3·7	1	−1·5	−1·5
10	3·124	3·313	− 1·4	3	+0·5	+0·5
11	3·867	4·056	− 1·2	3	+0·1	+0·3
12	4·074	4·220	− 2·2	2	−0·2	0·0
13	4·728	4·917	− 8·6	2	−2·9	−2·4
14	4·999	5·187	− 4·2	1	+3·9	+4·4
15	5·315	5·504	−15·3	2	−4·0	−3·5
16	5·576	5·722	−11·2	2	+3·1	+3·2
17	6·194	6·383	−22·7	2	−0·5	+0·2
18	6·293	6·483	−26·1	1	−2·5	−1·7
19	6·750	6·938	−30·9	2	−0·9	−0·2
20	6·845	6·992	−31·4	2	0·0	+0·1
21	7·368	7·557	−40·1	3	−1·4	−0·9
22	7·804	7·993	−43·5	2	+0·8	+1·1
23	8·396	8·584	−49·9	3	+0·7	+0·9
24	8·747	8·936	−53·1	3	+0·3	−0·3
25	9·277	9·466	−54·5	3	+1·3	+0·1
26	9·980	10·168	−55·5	1	−0·5	−2·4
27	10·260	10·449	−51·6	2	+1·7	−0·4
28	10·781	10·969	−47·0	2	+1·2	−1·0
29	11·226	0·184	−39·6	3	+2·7	+0·6

The following preliminary elements formed the basis of the least-squares solution.

$P = 11 \cdot 23$ days

$e = \cdot 05$

$\omega = 240°$

T = J.D. 2,421,917·089

K = 27·5 km. per sec.

$\gamma = -27 \cdot 8$ km. per sec.

OBSERVATION EQUATIONS

No.	Wt.															
1	2	1·000x	−	·362y	−	·154z	−	·985u	−	·001v	−1·037w	−3·9	= 0
2	2	1·000	−	·206	+	·177	−1·027	−	·228	−1·079	−1·2		
3	1	1·000	+	·358	+	·993	−	·967	−	·207	−	·981	+2·6		
4	3	1·000	+	·436	+1·020	−	·931	−	·192	−	·936	−1·5		
5	3	1·000	+	·583	+	·985	−	·837	−	·173	−	·825	+1·7		
6	2	1·000	+	·604	+	·969	−	·821	−	·165	−	·806	−1·3		
7	1	1·000	+	·646	+	·926	−	·785	−	·170	−	·765	−3·8		
8	2	1·000	+	·874	+	·375	−	·481	−	·090	−	·435	−0·7		
9	1	1·000	+	·932	+	·066	−	·335	−	·063	−	·285	+1·5		
10	3	1·000	+	·944	−	·027	−	·290	−	·050	−	·240	−0·5		
11	3	1·000	+	·964	−	·730	+	·105	+	·029	+	·140	−0·1		
12	2	1·000	+	·942	−	·856	+	·212	+	·001	+	·237	+0·2		
13	2	1·000	+	·803	−	·980	+	·518	+	·106	+	·512	+2·9		
14	1	1·000	+	·717	−	·904	+	·627	+	·125	+	·608	−3·9		
15	2	1·000	+	·601	−	·731	+	·737	+	·146	+	·705	+4·0		
16	2	1·000	+	·492	−	·533	+	·813	+	·000	+	·773	−3·1		
17	2	1·000	+	·203	+	·052	+	·930	+	·184	+	·883	+0·5		
18	1	1·000	+	·153	+1·506	+	·941	+	·194	+	·893	+2·5		
19	2	1·000	−	·080	+	·572	+	·955	+	·189	+	·916	+0·9		
20	2	1·000	−	·129	+	·647	+	·951	+	·004	+	·915	0·0		
21	3	1·000	−	·393	+	·938	+	·887	+	·181	+	·873	+1·4		
22	2	1·000	−	·597	+	·973	+	·777	+	·166	+	·786	−0·8		
23	3	1·000	−	·828	+	·683	+	·553	+	·122	+	·589	−0·7		
24	3	1·000	−	·929	+	·355	+	·384	+	·089	+	·431	−0·3		
25	3	1·000	−1·016	−	·245	+	·093	+	·030	+	·142	−1·3		
26	1	1·000	−	·986	−	·892	−	·320	−	·061	−	·297	+0·5		
27	2	1·000	−	·926	−1·001	−	·478	−	·096	−	·472	−1·7		
28	2	1·000	−	·743	−	·892	−	·739	−	·158	−	·764	−1·2		
29	3	1·000	−	·527	−	·504	−	·908	−	·199	−	·954	−2·7		

where

$$x = \delta\gamma$$
$$y = \delta K$$
$$z = K\delta e$$
$$u = -K\delta\omega$$
$$v = -\frac{10{,}000\ K\delta\mu}{(1-e^2)^{3/2}}$$
$$w = \frac{K\,\mu}{(1-e^2)^{3/2}}\ \delta T$$

NORMAL EQUATIONS

$$
\begin{array}{rrrrrrr}
61\cdot000x & +2\cdot474y & +6\cdot356z & -\cdot947u & -\cdot558v & -\cdot899w & -23\cdot400=0 \\
 & +29\cdot549 & -\cdot846 & -2\cdot536 & -\cdot880 & -2\cdot420 & +18\cdot690 \\
 & & +32\cdot996 & +\cdot113 & -\cdot018 & +\cdot176 & +8\cdot154 \\
 & & & +31\cdot262 & +5\cdot448 & +31\cdot195 & +30\cdot956 \\
 & & & & +1\cdot137 & +5\cdot448 & +5\cdot807 \\
 & & & & & +31\cdot200 & +31\cdot187
\end{array}
$$

The solution of the normal equations resulted in the following corrections:

$$
\begin{aligned}
\delta\gamma &= +\cdot42 \text{ km. per sec.} \\
\delta K &= -\cdot80 \text{ km. per sec.} \\
\delta e &= -\cdot013 \\
\delta\omega &= -3^\circ\cdot62 \\
\delta P &= -\ \cdot00023 \text{ days} \\
\delta T &= -\cdot146 \text{ days}
\end{aligned}
$$

and the corrected elements with their probable errors are:

$$
\begin{aligned}
P &= 11\cdot2298 & \pm\ \cdot0003 \text{ days} \\
e &= \cdot037 & \pm\ \cdot011 \\
\omega &= 236^\circ\cdot38 & \pm 13^\circ\cdot80 \\
K &= 26\cdot70 & \pm\ \cdot32 \text{ km. per sec.} \\
\gamma &= -27\cdot38 & \pm\ \cdot22 \text{ km. per sec.} \\
T &= \text{J.D. } 2{,}421{,}916\cdot943 & \pm\ \cdot435 \\
a \sin i &= 4{,}120{,}200 \text{ km.} \\
\frac{m_1^3 \sin^3 i}{(m+m_1)^2} &= \cdot011\odot
\end{aligned}
$$

The probable error of a normal place of weight unity is $\pm 1\cdot73$ km./sec. and the probable error of a plate is $\pm 1\cdot45$ km./sec. The least-squares solution reduced Σpv^2 from 213·7 to 155·5.

The final velocity curve with the normal places plotted as circles is given in the accompanying figure.

II. The Radial Velocities of Fifteen Stars

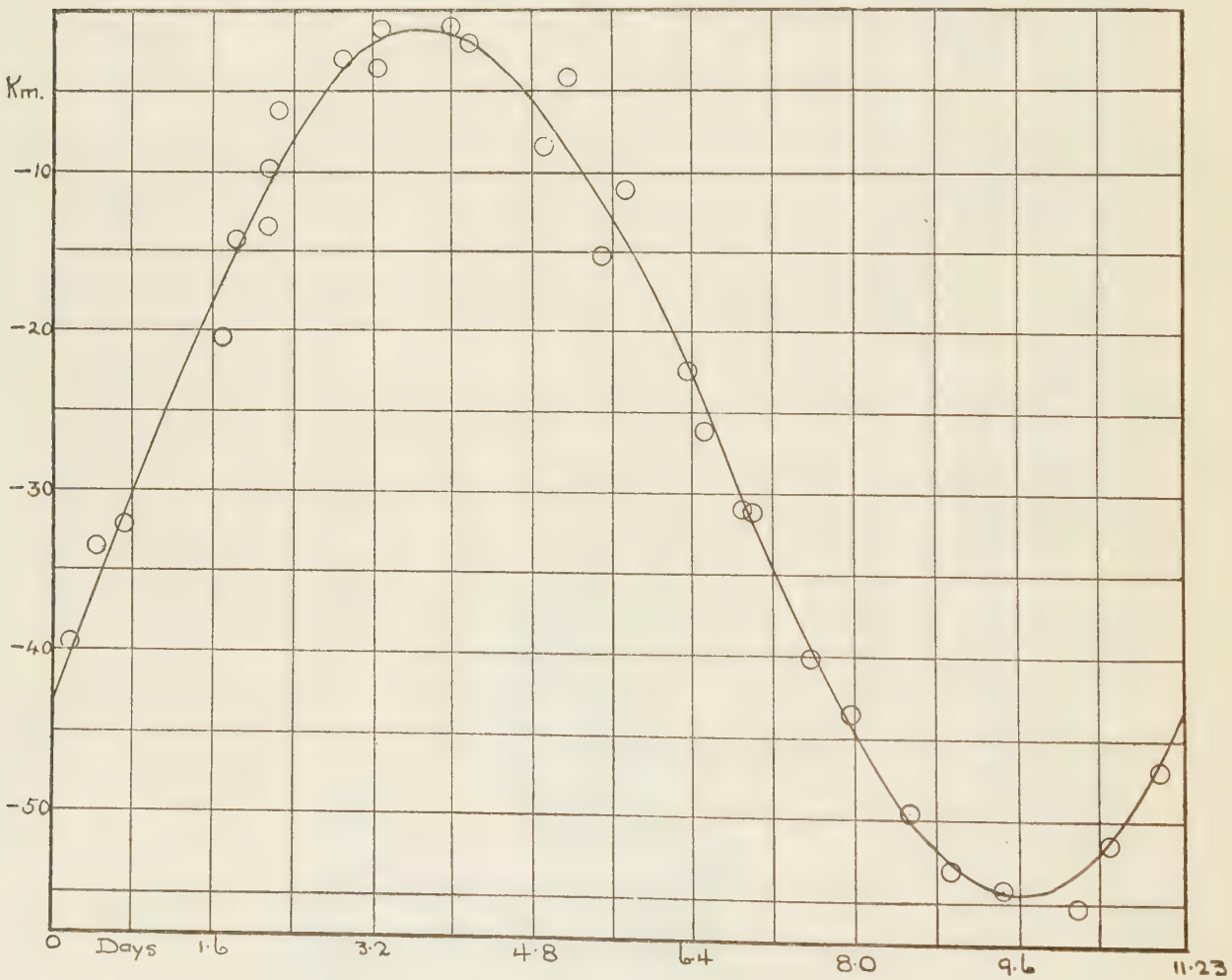
The measurements of the radial velocities, as tabulated below, completed the writer's programme during the months of June, July and August, 1924. In the case of four of these stars plates had previously been taken but had not been measured. The measures of these plates are included in the following table. Most of the spectra consist only of very diffuse lines of hydrogen, the K line of calcium and the 4481 line of magnesium.

Star	Type Mag.	Date G. M. T.	Rad. Vel.	Number of Lines	Quality	Remarks
H.R. 4816	Aop	1923 June 3·714	−14·6	21	Good	A good spectrum with many fine lines. λλ4077 and 4215 very strong. λ 4481 rather fuzzy.
$12^h\ 34{\cdot}4^m$	6·32	" 18·736	−18·6	23	"	
+36 °31′		1924 July 30·713	−15·6	17	"	
		Aug. 22·685	−14·6	17	Weak	
			−15·8 ±·6			
H.R. 5025	A5	1923 June 3·751	+ 1·2	11	Good	Lines in this spectrum rather diffuse.
$13^h\ 14{\cdot}5^m$	5·96	" 18·756	+ 1·0	12	"	
+35° 39′		July 6·727	− 9·3	5	Weak	
		1924 July 8·725	− 5·0	13	Good	
		Aug. 10·709	− 4·1	11	Fair	
		" 27·692	− 4·8	6	"	
			−3·0 ±1·0			
ζ Virginis	A2	1924 June 20·720	−14·3	4	Good	Very broad diffuse lines Hβ, Hγ, Hδ and K.
$13^h\ 29{\cdot}6^m$	3·44.	" 20·725	−16·2	4	"	
−0° 05′			**−15·3 ±·6**			
λ Boötis	Ao	1924 June 6·817	−15·5	4	Good	Very broad diffuse lines Hβ, Hγ, Hδ, Hε and K. Hγ, Hδ and K showed signs of doubling on one plate.
$14^h\ 12{\cdot}6^m$	4·26	" 30·732	−19·1	4	"	
+46° 33′		July 11·793	− 6·1	4	"	
		" 30·744	− 9·3	5	"	
		Aug. 3·719	−10·7	5	"	
		" 22·725	− 1·5	4	Weak	
		" 27·737	− 3·2	3	Fair	
		" 31·701	− 6·6	4	Good	
			−9·9 ±1·4			
Boss 3692	Ao	1924 June 16·752	−25·6	6	Good	Very broad diffuse lines Hβ, Hγ, Hδ, Hε 4481 and K. Hγ showed signs of doubling on two plates and the K line may be double on one plate.
(brighter star)	5·2	" 23·718	−10·3	5	"	
$14^h\ 18{\cdot}5^m$		July 11·773	−19·6	3	Fair	
+8° 54′		Aug. 3·749	−22·7	3	"	
		" 31·679	−19·0	3	"	
			−19·5 ±1·7			
ι Serpentis	A2	1924 June 30·741	−26·2	5	Good	Very broad diffuse lines Hβ, Hγ, Hδ, Hε, 4481 and K.
$15^h\ 37{\cdot}1^m$	4·49	" 30·749	−23·7	5	Fair	
+20° 00′		July 8·788	−25·1	4	Good	
		" 20·741	−27·1	6	"	
		July 30·783	−14·6	5	Fair	
		Aug. 3·776	−18·1	4	Weak	
		" 6·701	−11·9	3	Good	
		" 22·715	−17·6	4	Weak	
		" 31·658	−21·8	5	Good	
			−20·7 ±1·2			
γ Cor. Bor.	Ao	1924 June 20·816	−12·4	5	Good	Very broad diffuse lines of hydrogen also 4481 and K.
$15^h\ 38{\cdot}5^m$	3·8	" 20·822	−15·4	5	"	
+26° 37′		July 4·729	−18·4	5	"	
		" 4·735	−14·1	6	"	
		Aug. 26·672	−12·2	6	"	
		" 29·660	−11·1	5	"	
			−13·9 ± ·7			

Star	Type Mag.	Date G. M. T.	Rad. Vel.	Number of Lines	Quality	Remarks
ρ Herculis	Ao	1924 June 16·856	−25·8	5	Good	Very broad diffuse line
(brighter star)	4·52	" 23·840	−21·3	5	"	of hydrogen, also 4481
$17^h\ 20{\cdot}2^m$		July 7·721	−19·5	5	"	and K. On two plates
+37° 14′		" 11·792	−22·1	4	"	there are slight indica-
			−22·2 ± ·9			tions of doubling in the case of 4481 and K.
ρ Herculis	Ao	1924 June 23·854	−23·3	3	Good	Very broad diffuse lines
(fainter star)	5·47	" 30·863	−20·0	5	"	of hydrogen, also 4481
$17^h\ 20{\cdot}2^m$		July 7·733	−25·8	4	"	and K.
+37° 14′		" 8·885	−22·0	4	"	
			−22·7 ±1·1			
H.R. 6604	F5	1923 July 9·865	−38·2	16	Weak	The lines are diffuse.
$17^h\ 38{\cdot}8^m$	6·21	20·799	−42·7	17	"	
+14° 20′		1924 July 8·840	−43·5	23	Good	
		" 11·840	−49·2	20	"	
		" 30·855	−42·4	8	Weak	
		Aug. 20·724	−44·3	12	Fair	
			−43·4 ±1·0			
ϵ_1 Lyrae s.p.	A3	1924 June 16·894	−43·7	4	Good	Very broad lines hydro-
(brighter star)	5·06	" 23·874	−31·8	4	"	gen and K. Announced to be a binary by E. B. Frost, A.N. 177, p. 174, 1908.
$18^h\ 41^m$						
+39° 34′						
ϵ_1 Lyrae n.f.	A3	1924 June 23·899	−33·0	9	Good	Very broad lines of hydrogen, 4481 and K. W. S. Adams Ap. J., vol. 42, p. 181, gives $V_o = -37{\cdot}1$.
(fainter star)	6·02	July 7·817	−36·1	5	"	
$18^h\ 41^m$		" 11·887	−36·2	4	"	
+39° 34′						
			−35·1 ± ·7			
ϵ_2 Lyrae n.p.	A5	1924 July 30·814	−22·8	4	Good	Very broad lines of hydrogen, 4481 and K. On one plate there were very slight indications of doubling in the case of Hγ and 4481.
(brighter star)	5·14	Aug. 10·797	−34·1	4	Fair	
$18^h\ 41{\cdot}1^m$		" 20·687	−18·1	4	Good	
+39° 30′		" 20·822	−30·5	4	"	
		" 22·755	−16·9	4	Fair	
		" 22·794	−23·0	4	Good	
		" 27·765	−32·8	4	"	
		" 31·719	−33·9	4	"	
		" 31·763	−26·5	4	"	
			−26·5 ±1·5			
ϵ_2 Lyrae s.f.	A5	1924 July 7·802	−37·6	4	Good	Very broad lines of hydrogen and K.
(fainter star)	5·37	" 30·799	−26·2	4	"	
$18^h\ 41{\cdot}1^m$		Aug. 10·760	−40·8	3	"	
+39° 30′		" 13·706	−34·3	2	Weak	
		" 20·803	−33·3	2	"	
		" 22·774	−26·7	3	Fair	
		" 22·819	−21·3	2	Weak	
		" 27·800	−28·7	3	Fair	
		" 31·739	−34·6	4	Good	
		" 31·786	−30·2	3	Weak	
			−31·4 ±1·0			

Star	Type Mag.	Date G. M. T.	Rad. Vel.	Number of Lines	Quality	Remarks
		1921 Aug. 8·996	+ 4·4	10	Weak	A good spectrum with strong fuzzy lines. 4077 very strong. Suspected binary.
		1923 " 6·957	− 7·6	11	Good	
H.R. 8933	Ao	1924 July 30·968	− 5·5	12	"	
$23^h\ 26{\cdot}7^m$	6·23	Aug. 20·856	− 8·7	13	"	
$+27°\ 51'$		" 22·932	−12·5	13	Fair	
		" 31·899	−13·8	14	Good	
			−8·3 ±1·5			

In conclusion the writer wishes to acknowledge the assistance and guidance of the Director and other members of the Observatory staff, who have furnished advice and offered suggestions from time to time.



Radial Velocity Curve of Boss 6070

Dominion Astrophysical Observatory,
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THE ORBITS OF THE SPECTROSCOPIC COMPONENTS OF H. D. 216014

BY J. A. PEARCE

ABSTRACT

This massive binary system was discovered by Dr. J. S. Plaskett upon examining the first plate, on which the spectra of both components appeared, with a large relative displacement.

The spectrum is B0n, the diffuse character of the lines being reflected in the high probable error of an average plate, ±7·34 km.

The orbit was satisfactorily determined from 21 spectrograms, on 18 of which the secondary spectrum was measured. The principal elements are: P = 2·28754 days, e = 0·086, ω = 289°·31, K_1 = 225·0 km., K_2 = 258·8 km., and the minimum masses are 14·23 and 12·37 times the sun.

Eddington's theoretical considerations indicate an absolute magnitude of −2·50, which is in agreement with the value of −2·67, derived by assigning probable values of surface brightness −3·75, and density 0·08 with respect to the sun. The corresponding parallax is 0″·00095, a distance of 3,400 light years.

The calcium lines are sharp and give a velocity of −26·28 ±0·31 km., while the velocity of the system is −23·10 ±1·70 km.

Introduction

The star H.D. 216014, 1900 R.A. $22^h\ 44^m{\cdot}2$, Dec. +64° 32′, vis. mag. 6·83, spectral class B0, was discovered to be a binary by the Director upon examining the first plate. The lines were seen to be double and of wide separation, the relative velocity being approximately 400 kms. The investigation of this star of probable large mass was assigned to the writer who had recently joined the staff and commenced observing on the B-class programme.

The first observations seemed to be satisfied by a period of 6·85 days, which combined with the unusually large amplitude, would make the system a very massive one. The sixth observation, however, demanded the submultiple 1/3 and the shorter period of 2·2891 days was later adopted as the preliminary value.

The Spectrum

The spectrum is classified in the Henry Draper Catalogue as B3, with the following remark: "The line Hβ is not seen as a dark line, and is suspected to be bright." The type, however, is really B0n. Two of the single-lined plates were obtained when the stars were crossing the line of sight, the observed velocity being identical with that of the system. These show a fair spectrum, the lines of which are given in Table I.

TABLE I—THE SPECTRUM OF H.D. 216014—PLATE 11034

I—Lines Measured for Rad. Vel.			II—Lines Observed but not Measured	
Wavelength	Int.	Atom	Wavelength	Atom
*4921·929	4	He	4676·246	Oxygen
*4861·326	8	Hβ	4661·650	"
4713·143	3	He	4649·148	"
4685·74	4	He+	4596·189	"
4650·75	4	C++	4590·983	"
4574·737	1	SiIII	4437·549	Helium
4567·824	1	SiIII	4416·974	Oxygen
4552·611	1	SiIII	4414·888	"
4481·230	2	Mg+	4349·435	"
*4471·477	5	He	4319·647	"
*4387·928	4	He	4317·160	"
*4340·467	10	Hγ	4253·77	Sulphur
4267·16	2	C+	4168·97	Helium
*4143·759	4	He	4119·222	Oxygen
*4120·812	2	He	4072·156	"
4116·104	2	SiIV	4069·788	" blend
*4101·738	9	Hδ		
4088·863	3	SiIV		
4075·869	2	OII	III—Unknown Lines Measured	
*4026·189	5	He		
4009·267	2	He	4428·18 Mg+ (4428·00)	
*3970·075	8	Hε	4285·79 S (4285·13)	
3968·476	4	Ca+(H)		
3933·667	5	Ca+(K)		

Part I contains the lines measured for determining the radial velocity, together with their intensity and identification. Part II contains the weak lines observed but not measured. Two faint unknown lines were measured for wavelength and are given in Part III. λ4428·18 is very probably due to Mg+, λ4427·995 although no traces of λλ4433·991 or 4390·585 were observed. λ4285·79 may possibly be λ4285·13 which with λ4253·77 are attributed to abnormal sulphur by Lockyer[1]. The absence of the Pickering series and of ionized nitrogen forbids a classification earlier than B0, while the presence of λ4686 He+ fixes the type definitely as B0. As in many B0-B1 stars many lines of oxygen occur, but here the lines are very weak and not suitable for measurement. The diffuse character of the lines is shown in the rather high probable error of an average plate, ±7·34 km. Both components appear to have identical spectra, the asterisks in Table I denoting those lines measured as double in an average plate. The lines of calcium are strong, and compared with the nebulous nature of the other lines, are narrow admitting of accurate measurement, as is shown by the probable error of their mean velocity, ±0·31 km.

The suspected emission of Hβ referred to in the quotation above is not confirmed, it appeared as a good absorption line on all the plates.

[1] The references are on page 178.

The Observations

Before the star became out of reach in the west, nineteen plates were secured with the I-prism spectrograph and IS camera, having a dispersion of 49 A per mm. at Hγ. Two observations with the IM camera, dispersion 29A per mm. at Hγ, are marked with an asterisk in Table II. The emulsion used throughout was Seed 30. The plates were measured on a Toepfer micrometer engine having a binocular eyepiece which was found to be more restful on the eyes than the ordinary single-ocular machine. Four of the plates were remeasured and the means accepted as the final values of the velocities. The measures were difficult, and somewhat uncertain, on account of the diffuse nature of the lines, but in general owing to the large relative velocity the two components were clearly separated. Had the amplitudes been about one-half their actual values, considerable difficulty would have been experienced in obtaining satisfactory measures, as separations of 150 km. would certainly have appeared as single lines.

TABLE II—JOURNAL OF OBSERVATIONS—H.D. 216014

No.	Plate	Julian Date 2,424,000+	Phase from 2,424,076	Brighter Component				Fainter Component				Calcium		
				Vel.	Lines	Wt.	(O-C)	Vel.	Lines	Wt.	(O-C)	Vel.	Lines	(O-M)
1	10891	078·8014	0·5139	−210·9	6	3	+12·8	+168·3	6	1·2	−39·5	−31·5	K	−5·2
2	10905	081·7243	1·1492	+166·5	4	1	+18·6	−222·8	4	0·6	− 3·2	.....	.....	.....
3	10917	092·6841	0·6713	−181·8	7	2	−18·0	+164·3	7	1·2	+25·4	−26·1	K, K	+0·2
4	10920	098·7722	2·1843	− 95·0	5	1	+14·4	+ 68·9	6	0·6	− 7·4	−22·9	H, K	+3·4
5	10925	099·7549	0·8795	− 28·0	11	2	+ 1·9	.....	.....	....	.....	−28·4	H, K	−2·1
6	10934	111·6459	1·3328	+204·1	10	3	− 0·8	−290·0	7	2·0	− 5·0	−27·8	H, K	−1·5
7	10956	116·6446	1·7564	+ 97·4	10	3	−10·4	−209·5	9	1·2	−35·9	−29·0	H, K	−2·7
8	10976	117·5972	0·4215	−237·5	11	3	+ 1·7	+232·2	9	2·0	+ 6·7	−29·2	H, K	−2·9
9	10983	117·7715	0·5958	−213·4	10	2	−15·5	+209·9	10	1·2	+31·9	−29·3	K	−3·0
10	10993	119·5965	0·1332	−228·4	11	2	−23·4	+205·4	10	1·2	+19·5	−30·0	H, K	−3·7
11	11012	127·6626	1·3367	+206·9	10	3	+ 1·6	−274·1	9	2·0	+11·3	−27·4	K	−1·1
*12	11029	128·6875	0·0741	−196·0	10	3	−11·3	+161·8	9	2·0	− 1·2	−18·9	H, K	+7·4
13	11034	138·6536	0·8900	− 26·0	21	3	− 4·0	.....	.....	....	.....	−27·9	K	−1·6
14	11048	139·6557	1·8921	+ 69·2	8	1	+29·0	− 90·2	7	2·0	+ 5·4	−27·6	H, K	−1·3
15	11063	141·6355	1·5844	+172·2	7	3	− 4·2	−239·2	8	2·0	+13·2	−23·3	K	+3·0
16	11083	142·7625	0·4238	−235·3	6	3	+ 3·7	+216·5	6	2·0	− 8·8	.....	.....	.....
*17	11091	143·6048	1·2661	+191·6	8	3	− 0·6	−273·9	8	2·0	− 3·3	−18·6	K	+7·7
18	11114	144·6439	0·0177	−164·8	7	2	− 1·4	+181·6	7	0·6	+43·2	−36·1	K	−9·8
19	11130	155·1264	0·8500	− 52·5	5	1	− 1·7	.....	.....	....	.....	.....	.....	.....
20	11130A	159·1048	0·2534	−236·4	5	1	− 4·2	+244·0	5	0·6	+26·4	−17·0	H, K	+9·3
21	11143	166·0840	0·3699	−227·7	11	3	+13·7	+214·2	10	2·0	−14·0	−20·6	H, K	+5·7

* IM Plates.

The columns of Table II are self-explanatory, but it should be noted that the Julian days of the last three observations are expressed in the "new style", i.e., beginning at Greenwich Civil Noon, and therefore a correction of 0·5000 of a day must be subtracted from the given times in order to harmonize them with the earlier observations.

The Spectroscopic Orbit

The secondary spectrum was measured on eighteen of the twenty-one plates, so that the elements were determined from thirty-nine observations. Preliminary values of the elements were obtained by a graphical method in use at the observatory. It was decided to employ the Lehmann-Filhés method of correcting the elements and to include a correction for a period as the observations only extended over thirty-eight cycles. Mention should be made of the system of weighting adopted as this is very important when large residuals are concerned. The weights assigned depend upon the number of lines measured, the character of the exposure of the plate and the factor 0·6 which expresses the degree of precision of the fainter measures with respect to those of the brighter component. The sum of the weights is 74·4, of which 26·4, or 35 per cent, is due to the secondary. The resulting probable errors of the brighter and fainter components were ±7·34 and ±12·57 km.

TABLE III—OBSERVATION EQUATIONS—H.D. 216014

Primary									
2.....	1	1·000t	+ ·837u	.....	+·233w	−·153x	−·153y	−17·312z	− 1·1	= 0
7.....	3	1·000	+ ·953	.....	+·199	−·106	−·095	− 6·330	+ 1·9	
11.....	3	1·000	+1·107	.....	+·115	−·052	−·032	− 1·632	+ 1·1	
6.....	3	1·000	+1·020	.....	+·106	−·047	−·027	− ·937	+ 4·7	
15.....	3	1·000	+ ·885	.....	−·162	+·093	+·109	+ 7·045	+ 6·1	
7.....	3	1·000	+ ·555	.....	−·214	+·169	+·166	+ 6·584	+ 6·7	
14.....	1	1·000	+ ·296	.....	−·155	+·195	+·181	+11·345	−23·5	
4.....	1	1·000	− ·414	.....	+·132	+·180	+·164	+ 3·591	−18·9	
18.....	2	1·000	− ·587	.....	+·191	+·156	+·146	+ 9·917	+11·9	
12.....	3	1·000	− ·704	.....	+·216	+·132	+·129	+ 6·672	+16·9	
10.....	2	1·000	− ·798	.....	+·219	+·106	+·109	+ 4·645	+28·0	
20.....	1	1·000	− ·904	.....	+·188	+·061	+·073	+ 5·953	+12·1	
21.....	3	1·000	− ·970	.....	+·097	−·001	+·019	+ 1·695	−11·4	
16.....	3	1·000	− ·970	.....	+·018	−·042	−·020	− 1·288	− 3·8	
8.....	3	1·000	− ·966	.....	+·000	−·051	−·029	− 1·162	− 0·6	
1.....	3	1·000	− ·868	.....	−·143	−·122	−·109	− ·195	− 5·2	
9.....	2	1·000	− ·782	.....	−·196	−·155	−·142	− 5·806	+16·6	
3.....	2	1·000	− ·586	.....	−·236	−·200	−·200	− 3·146	+29·0	
19.....	1	1·000	− ·190	.....	−·155	−·241	−·234	−18·161	−11·1	
13.....	3	1·000	− ·022	.....	−·086	−·247	−·270	−16·635	+ 0·3	
5.....	2	1·000	+ ·032	.....	−·063	−·247	−·271	− 6·175	+14·3	
Secondary									
2.....	0·6	1·000	.....	− ·837v	−·268	+·176	+·176	+ ·840	−14·4	
7.....	2·0	1·000	.....	− ·953	−·228	+·122	+·109	+ 7·272	+ 6·8	
11.....	2·0	1·000	.....	−1·017	−·132	+·059	+·037	+ 1·875	− 9·6	
6.....	2·0	1·000	.....	−1·020	−·122	+·054	+·031	+ 1·077	+ 5·6	
15.....	2·0	1·000	.....	− ·885	+·187	−·107	−·125	− 8·094	−10·4	
7.....	1·2	1·000	.....	− ·555	+·246	−·194	−·191	− 7·564	+45·2	
14.....	2·0	1·000	.....	− ·296	+·178	−·224	−·208	−13·034	− 7·0	
4.....	0·6	1·000	.....	+ ·414	−·152	−·207	−·189	− 4·125	+17·2	
18.....	0·6	1·000	.....	+ ·587	−·219	−·179	−·168	−11·394	−50·5	
12.....	2·0	1·000	.....	+ ·704	−·248	−·152	−·148	− 7·665	+ 0·8	
10.....	1·2	1·000	.....	+ ·798	−·252	−·121	−·125	− 5·337	−19·9	
20.....	0·6	1·000	.....	+ ·904	−·216	−·070	−·084	− 6·840	−31·0	
21.....	2·0	1·000	.....	+ ·970	−·111	+·001	−·022	− 1·948	+15·7	
16.....	2·0	1·000	.....	+ ·970	−·021	+·048	+·022	+ 1·480	+13·4	
8.....	2·0	1·000	.....	+ ·966	−·000	+·059	+·033	+ 1·335	− 3·4	
1.....	1·2	1·000	.....	+ ·868	+·164	+·141	+·120	+ ·224	+35·1	
9.....	1·2	1·000	.....	+ ·782	+·226	+·177	+·163	+ 6·671	−28·5	
3.....	1·2	1·000	.....	+ ·586	+·271	+·229	+·230	+ 3·614	−33·5	

The symbols in the thirty-nine observations equations given in Table III and in the normal equations have the following significance:

$$t = \delta\gamma \qquad x = -1000\,\delta\omega$$
$$u = \delta K_1 \qquad y = 1000\,\frac{\delta T.\mu}{(1-e^2)^{3/2}}$$
$$v = \delta K_2$$
$$w = 1000\,\delta e \qquad z = -1000\,\frac{\delta\mu}{(1-e^2)^{3/2}}$$

The observation equations give rise to the following normal equations:

+74·400t	− 6·027u	+ 2·493v	− ·210w	−1·629x	−1·625y	− 68·867z	+ 18·186 = 0
	+29·616	+ ·202	− ·013	+ ·072	+ ·027	− 19·512	− 37·523
		+18·648	− ·011	+ ·156	+ ·116	− 4·719	− 23·123
			+2·075	+ ·266	+ ·296	+ 6·930	+ 11·804
				+1·337	+1·299	+ 58·067	− 9·901
					+ ·028	+ 1·417	− 2·067
						+614·946	+1167·704

These yielded the following values of the unknowns:

t = − 2·1876	whence	$\delta\gamma$ = −2·19		±1·70 km.
u = + 0·0018		δK_1 = 0·00		±2·66 km.
v = + 0·3231		δK_2 = +0·32		±3·33 km.
w = − 13·9441		δe = −0·014		±0·007
x = − 75·2245		$\delta\omega$ = +4°·31		±4°·80
y = +169·9290		δT = +0·06098		±0·03252 days
z = − 1·8989		δP = −0·00156		±0·00047 days

In order to see whether the inclusion of the less certain measures of the fainter component materially contributed in defining the elements, or whether they produced a detrimental effect, a second solution was carried out for the brighter component only. Using the same symbols as before (v omitted of course) we have the six normal equations:

+48·000t	− 6·027u	+ ·511w	−1·460x	−1·162y	− 17·682z	+207·200 = 0
	+29·347	+ ·068	+ ·021	+ ·013	− 16·154	− 26·238
		+1·175	+ ·2645	+ ·278	+ 9·896	+ 2·880
			+ ·826	+ ·827	+ 38·220	− ·254
				+ ·015	+ ·588	− 1·660
					+411·686	+490·440

These resulted in:

t = − 3·9490	whence	$\delta\gamma$ = −3·95		±2·13 km.
u = + 0·2571		δK_1 = +0·26		±2·41 km.
w = − 6·6601		δe = −0·007		±0·012
x = −102·0932		$\delta\omega$ = +5°·84		±6°·09
y = +157·33		δT = +0·05646		±0·03899 days
z = − 1·1913		δP = −0·00098		±0·00052 days

K_2 with its probable error was found to be

δK_2 = +0·92 ±3·47 km.

Applying these corrections to the preliminary elements we obtain the final ones given in Table IV.

TABLE IV—ELEMENTS OF THE ORBIT—H.D. 216014

	Preliminary	1st Solution Both Components		2nd Solution Brighter Component only	
Period	P 2·2891 days	2·28754	±0·00047 days	2·28812	±0·00052days
Eccentricity	e 0·10	0·086	±0·007	0·093	±0·012
Longitude of periastron	ω_1 285·0	289·31	±4·80	290·84	±6·09
" "	ω_2 105·0	109·31	±4·80	110·84	±6·09
Semi-amplitude of primary	K_1 225·0 km.	225·0	±2·66 km.	225·26	±2·41 km.
Semi-amplitude of secondary	K_2 258·5 km.	258·8	±3·33 km.	259·42	±3·47 km.
Periastron passage	T J.D.2,424,076·940	−4077·0010	±0·0325	−4076·9965	±0·0389
Velocity of the system	γ −20·82 km.	−23·10	±1·70 km.	−24·79	±2·13 km.
Velocity of calcium	Ca+−26·28 km.	−26·28	±0·31 km.	−26·28	±0·31 km.

The elements of solution II differ little from those of solution I, but they are defined with much greater precision by the first solution, and so the inclusion of the fainter measures was justifiable, as we would expect from theory. We are here, however, dealing with diffuse lines and not with well-defined ones, and it is questionable whether in this case the solution would have been improved had the factor of precision been, perhaps, 0·4.

The elements of solution I are therefore considered as the elements of the orbit, and they were used in computing the ephemeris for the velocity curve. ΣPvv was reduced from 17958·82 to 14398·54, or by 20 per cent. The probable error of an observation of weight unity is ±14·3 km., and of a single plate is ±7·34 km.

The Mass of the System

The projected semi-axis major and the minimum masses computed from the elements are:

$$(a_1 + a_2) \sin i = 15{,}162{,}000 \text{ km.} = 22 \text{ solar radii.}$$
$$m_1 \sin^3 i = 14{\cdot}23 \odot$$
$$m_2 \sin^3 i = 12{\cdot}37 \odot$$
$$(m_1 + m_2) \sin^3 i = 26{\cdot}60 \odot$$

But these minimum masses must be divided by $\sin^3 i$, the average value of which is 0·65, so that the actual masses may be considerably larger. The system is among the six most massive systems thus far determined.[2]

The Absolute Magnitude

In attempting to compute the absolute magnitude and thus determine the distance, we shall take the minimum mass and assign conservative values for this type of star. Adopting for the surface brightness $j = -3{\cdot}75$, a mean between the values of Russell[3] and Hertzsprung[4], and a temperature of 20000°, which is below the estimates of Russell[5] and Fowler and Milne[6], and a density $\rho = 0{\cdot}08$, given by Seares[7] for a B0 giant of mass ten times the sun, we have by the luminosity method $M = -2{\cdot}67$. Reducing the bolometric absolute magnitude as given by Eddington[8] to the visual absolute magnitude we find for these conditions $M = -2{\cdot}50$. Combining the mean $M = -2{\cdot}58$ with the apparent magnitude $m = 7{\cdot}53$ the resulting parallax is $0''{\cdot}00095$, over 1050 parsecs or more than 3400 light years.

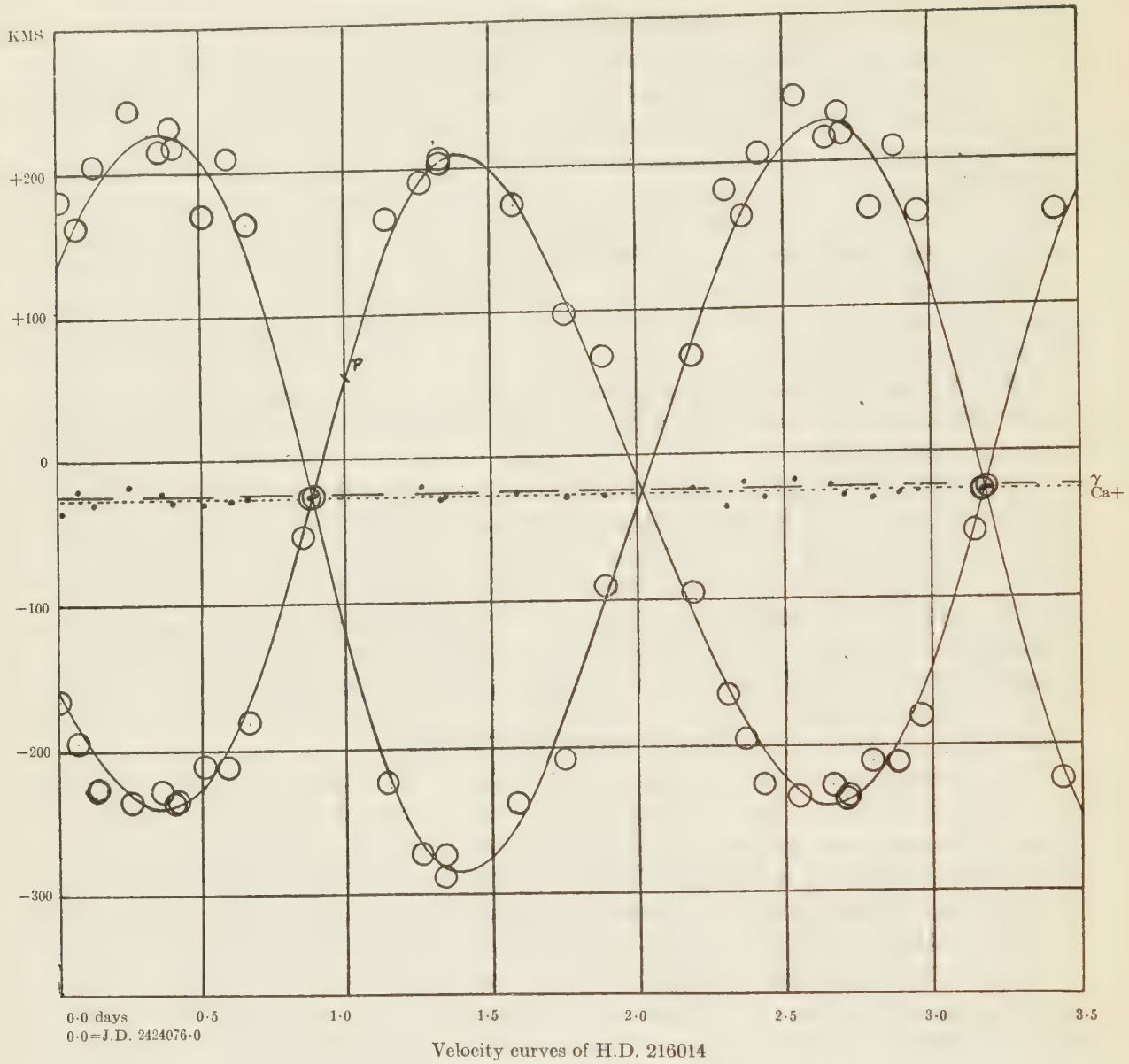
The theoretical diameter as computed by the formulae of Russell[9] or Seares[10] is $0''{\cdot}000048$, which when combined with the linear diameter of $5{\cdot}40\,\odot$, 4,667,000 miles, gives the same parallax.

The adoption of higher values of the surface brightness, lower density and of the possible mass of $21{\cdot}9\,\odot$ for the brighter component, corresponding to the average value of the inclination would, of course, place the system at a greater distance. Indeed, the density is very probably lower than 0·08, since the ratio of the radiation pressure of gravitational pull $(1-\beta)$ is approximately 0·617[8]. It is sufficient, however, to establish by using the minimum mass and the conservative assumptions above, that the parallax cannot exceed $0''{\cdot}00095$, which makes the minimum distance 3400 light years.

The Velocity of Calcium

In contradistinction to the diffuse hydrogen and helium lines the H and K lines of ionized calcium are strong and sharp, giving a constant velocity of $-26{\cdot}28 \pm 0{\cdot}31$ km. This value is very close to that found for the velocity of the system, $-23{\cdot}10 \pm 1{\cdot}70$ km., and raises the question as to the location of the calcium vapour. In the case of this massive binary of short period, it is reasonable to expect that the lines, if due to a calcium envelope enshrouding the pair of stars, should exhibit a measurable oscillation, on account of the very high rotational velocity, whereas no such oscillation was observed. If considered as an interstellar cloud in space, quite apart from the spectroscopic binary, the observations indicate that this vapour has a velocity of approach of 15 km. per sec., as the component of the solar motion in this direction is $-11{\cdot}40$ km. only. Differences of this order and even greater, between the velocity of calcium and the component of the solar motion, do not appear to be unusual among the O-and B-type stars, as has been shown by Dr. Plaskett [11], Young and others[12], so that this view is quite plausible.

An alternative explanation is to place the calcium cloud within the star's gravitational domain, at a distance of 40 to 50 astronomical units say. It would then hardly be expected to show the motions of the rotating binary, and the resulting lines would be stationary, possessing approximately the velocity of the system. This alternative location for the ionized calcium is not inconsistent with the well established hypothesis of Dr. Plaskett[11] in regard to stationary clouds of calcium and sodium vapour.



Velocity curves of H.D. 216014

The observations are shown in the graph as circles of radius 7 km., the round dots represent the velocities of the H and K lines, the dotted line is the calcium axis, while the γ axis is shown by the broken line.

Dominion Astrophysical Observatory,
Victoria, B.C.
April, 1925.

REFERENCES

[1] Lockyer, Roy. Soc., Proc., LXXX, 50, 1908.
[2] Pub. D.A.O., II, p. 154.
[3] Pub. A.S.P., *32*, 307; *34*, 92.
[4] Mt. W. Cont. *10*, 399.
[5] R.A.S.C., XVIII, 153.
[6] M.N., LXXXIV, 505.
[7] Mt. W. Cont. *10*, 404.
[8] Pub. D.A.O., II, p. 329, Table XIV.
[9] Pub. A.S.P., *32*, 315, Table IV.
[10] Mt. W. Cont. *10*, 402.
[11] Pub. D.A.O., II, No. 16.
[12] Pub. D.A.O., I, No. 17.

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THE ORBITS OF TWO DOUBLE-LINED B-TYPE BINARIES

BY J. S. PLASKETT

Abstract.—The two B-type binaries discussed in this publication were discovered here in the course of the investigation of B-type stars. The first one ζ_2 Coronae Borealis of type B8 has a period of 12·585 days, eccentricity of 0·03 and semi-amplitudes of 134·8 and 137·7 km. The masses of the two components are 13·35 and 13·06 times the sun respectively, unusually high for B8. By two independent methods the absolute magnitude is −3·2 and the parallax 0″·0016, a distance of about 2,000 light years. The second binary H.D. 25833 is of type B3, has a period of 2·02858 days, eccentricity of 0·0512, and semi-amplitudes of 164·97 and 187·32 km. corresponding to minimum masses 4·86 and 4·29 times the sun. By similar methods to the above the absolute magnitude is −1·5 corresponding to a parallax of 0″·00166, nearly 2,000 light years. The distances of both these stars, and these are minimum values, are greater than generally accepted for the B's.

Introduction

In a programme for the determination of the radial velocities of all the B-type stars brighter than 7·5 visual magnitude and north of declination −10°, recently undertaken by Mr. J. A. Pearce and the writer, it is inevitable that many stars of varying radial velocity, probably one-fourth of the number observed, will be encountered. For those spectroscopic binaries which are of small range of velocity, it is our plan to obtain six or eight plates at fairly uniformly spaced intervals and accept their mean velocity as the approximate velocity of the system. For any of special interest and for those of large range, particularly where both components are visible, we propose to determine the orbits whenever the lines are even moderately well measurable. The two orbits following are of double lined B-type spectra and Mr. Pearce is publishing a third simultaneously.

The Orbit of ζ_2 Coronae Borealis

It seems curious that the binary character of this star, H.D. 139892, R.A. 15h. 35·6m., Dec. +36° 58′, visual magnitude 5·07, spectral type B8, should not have been earlier discovered as it is of the fifth magnitude and must hence have been spectroscopically observed previously. Furthermore the spectrum shows doubled lines which, though broad and fuzzy, are of fairly wide separation. It was first observed by me on March 16, 1924, but on this plate the lines were single and its binary character was discovered by Mr. W. H. Christie on May 4 when the relative separation of the lines was 220 km. At frequent intervals between the first date and August 28, 1924, 36 spectrograms were obtained. Of these 32 were used in the determination of the orbit, the remaining four being omitted on account of such close proximity to the crossing points that the doubled lines became blended and even approximate measures were impossible.

The spectrum is of type B8n with broad, strong and ill-defined lines of hydrogen and weak diffuse lines of helium. The spectrum is difficult to measure for if the plate is exposed sufficiently to make the hydrogen lines reasonably measurable, the helium lines are entirely blocked up. The difficulties are of course much increased by the double lines and consequently the measures are uncertain as indicated by the probable errors per plate of

$\pm 11 \cdot 8$ km. per second for the brighter component and $\pm 15 \cdot 1$ for the fainter. The only lines measured or measurable on these spectra are hydrogen Hβ, Hγ, Hδ, Hϵ, helium 4922*, 4472, 4388*, 4143*, 4026, Mg 4481. The lines marked with an asterisk were only measured on two or three plates when the spectrum was single and are quite unusuable when doubled. The average number of lines measured is five and the maximum nine.

The 32 observations used in the determination of the orbit, all of which, except two obtained with the shorter focus camera, were made with the medium focus camera giving linear dispersion of 29 A to the millimetre at Hγ, are given in the table below arranged in order of phase. The measures were mostly made on the Gaertner measuring microscope with a binocular eyepiece which I have found exceedingly satisfactory and not so tiring for the eyes as the monocular attachment. When the measure seemed uncertain or gave a higher than normal residual, the plate was remeasured and the velocity used is in every case the simple mean of the two measures. In Table I in successive columns are given the plate number, Julian date of the observation, the final phase computed from the corrected period and time of periastron, the observed and computed velocities of the brighter component with the residual and the observed and computed velocities of the fainter component with residual.

TABLE I.—OBSERVATIONS OF ζ_2 CORONAE BOREALIS

Plate Number	Julian Date	Final Phase	Velocities Brighter			Velocities Fainter		
			Observed	Computed	O-C	Observed	Computed	O-C
10298	3,982·803	1·273	−141·1	−113·56	−27·5	+ 73·5	+ 56·14	+17·4
10524	4,020·740	1·456	−119·7	−123·27	+ 3·6	+ 78·3	+ 66·06	+12·2
10356	3,995·703	1·589	−123·7	−129·78	+ 6·1	+ 63·6	+ 72·71	− 9·1
10213	3,970·777	1·832	−141·3	−140·31	− 1·0	+ 86·8	+ 83·46	+ 3·3
10385	3,996·711	2·596	−159·8	−161·29	+ 1·5	+109·4	+104·89	+ 4·5
10478	4,009·674	2·975	−168·0	−164·39	− 3·6	+ 99·8	+108·06	− 8·3
10308	3,984·821	3·291	−167·8	−163·24	− 4·6	+ 95·0	+106·89	−11·9
10025	3,934·749	3·559	−160·1	−159·75	− 0·3	+106·0	+103·32	+ 2·7
10394	3,997·772	3·658	−150·5	−157·90	+ 7·4	+100·2	+101·44	− 1·2
10228	3,972·764	3·819	−150·9	−154·22	+ 3·3	+ 89·0	+ 97·68	− 8·7
10402	3,998·692	4·578	−142·0	−127·43	−14·6	+ 91·5	+ 70·31	+21·2
9898	3,910·809	4·789	−119·7	−117·55	− 2·1	+101·6	+ 60·22	+41·4
10319	3,987·729	6·199	− 34·2	− 35·53	+ 1·3			
10155	3,962·709	6·349	− 42·6	− 25·96	−16·6			
9760	3,861·935	6·254	− 11·8	− 32·12	+20·3			
10252	3,975·754	6·809	+ 1·5	+ 2·87	− 1·4	−107·3	− 62·77	−44·5
10559	4,026·658	7·374	+ 53·4	+ 36·21	+17·2	−112·9	− 96·84	−16·1
10054	3,938·847	7·657	+ 62·4	+ 51·46	+10·9	−133·6	−112·41	−21·2
10260	3,976·722	7·777	+ 65·7	+ 57·44	+ 8·3	−106·3	−118·53	+12·2
10168	3,964·717	8·357	+ 77·8	+ 82·37	− 4·6	−134·5	−143·99	+ 9·5
10433	4,002·692	8·578	+ 92·3	+ 89·77	+ 2·5	−151·0	−151·55	+ 0·6
10094	3,952·710	8·935	+ 91·8	+ 98·83	− 7·0	−146·0	−160·81	+14·8
10342	3,990·701	9·171	+ 78·6	+102·71	−24·1	−157·4	−164·77	+ 7·4
10269	3,978·738	9·793	+ 93·1	+104·28	−11·2	−171·2	−166·37	− 4·8
10511	4,016·673	9·974	+103·0	+102·28	+ 0·7	−145·4	−164·33	+18·9
10177	3,966·708	10·338	+ 97·6	+ 94·90	+ 2·7	−161·1	−156·79	− 4·3
10072	3,941·776	10·586	+ 99·1	+ 87·31	−11·8	−143·7	−149·03	+ 5·3
10453	4,004·742	10·628	+ 67·6	+ 85·81	−18·2	−137·2	−147·50	+10·3
10278	3,979·789	10·844	+ 70·8	+ 77·33	− 6·5	−132·8	−138·84	+ 6·0
10456	4,005·694	11·580	+ 51·1	+ 38·70	−12·4	−129·2	− 99·39	−29·8
10114	3,955·710	11·935	+ 32·3	+ 15·90	+16·4	− 89·9	− 76·10	−13·8
10462	4,006·680	12·566	− 25·9	− 28·28	+ 2·4			

The preliminary elements were determined by trial and error by aid of a serfes oi velocity curves for different eccentricities and longitudes of the apse, and are given in Table III below. As usual it was felt necessary to carry out a least-squares correction to these elements especially as the interval covered by the observations was short, only about 14 cycles, with no early observations to accurately determine the period. For this correction I am indebted to an undergraduate in mathematics at Edmonton, Mr. F. G. Young, who was anxious to obtain experience in this work and applied through Professor J. W. Campbell for the material. This correction, which was carried through by the method of Lehmann-Filhés, was applied to all the elements except ω of both components and contained six unknowns and sixty observation equations. It was consequently a laborious piece of work and I am much indebted to Mr. Young for the accurate and satisfactory solution.

From the preliminary elements of Table III and making

$$\begin{aligned} x &= \delta\gamma \\ y_1 &= \delta K_1 \\ y_2 &= \delta K_2 \\ u &= 132\delta e \\ v &= \frac{132\mu}{(1-e^2)^{3/2}}\,\delta T \\ w &= \frac{13200}{(1-e^2)^{3/2}}\,\delta\mu \end{aligned}$$

there resulted the observation equations of Table II.

TABLE II.—OBSERVATION EQUATIONS

Number	Wt.	x	y_1	y_2	u	v	w	
1	1	1·000	−0·655	+0·000	+1·011	+0·814	+1·037	+22·700 =0
2	1	1·000	−0·708	0·000	−1·020	+0·757	+1·249	− 5·800
3	1	1·000	−0·767	0·000	−1·002	+0·683	+0·958	− 9·500
4	1	1·000	−0·852	0·000	−0·906	+0·551	+0·636	− 3·200
5	1	1·000	−0·986	0·000	−0·338	+0·173	+0·244	− 2·300
6	1	1·000	−1·000	0·000	+0·024	−0·012	−0·019	+ 4·000
7	1	1·000	−0·983	0·000	+0·358	−0·180	−0·232	+ 6·000
8	1	1·000	−0·941	0·000	+0·631	−0·326	−0·258	+ 3·800
9	1	1·000	−0·938	0·000	+0·648	−0·336	−0·478	− 5·300
10	1	1·000	−0·902	0·000	+0·774	−0·414	−0·486	− 0·100
11	1	1·000	−0·703	0·000	+0·985	−0·662	−0·947	+17·200
12	1	1·000	−0·591	0·000	+0·937	−0·743	−0·411	+ 9·600
13	1	1·000	−0·032	0·000	+0·063	−0·902	−1·192	− 2·000
14	1	1·000	+0·049	0·000	−0·096	−0·902	−0·967	+17·100
15	1	1·000	+0·061	0·000	−0·118	−0·901	−0·058	−12·200
16	1	1·000	+0·248	0·000	−0·470	−0·877	−1·055	− 0·800
17	1	1·000	+0·462	0·000	−0·803	−0·810	−1·386	−24·500
18	1	1·000	+0·612	0·000	−0·951	−0·730	−0·608	−13 600
19	1	1 000	+0·639	0 000	−0·967	−0·711	−0·862	−13·400
20	1	1·000	+0·826	0·000	−0·921	−0·533	−0·582	− 0·800
21	1	1·000	+0·870	0·000	−0·850	−0·470	−0·691	− 9·500
22	1	1·000	+0·951	0·000	−0·587	−0·301	−0·293	+ 1·700

TABLE II—OBSERVATION EQUATIONS—*Concluded*

Number	Wt.	x	y_1	y_2	u	v	w	
23	1	1·000	+0·975	0·000	−0·429	−0·216	−0·292	+18·100
24	1	1·000	+0·996	0·000	+0·188	+0·095	+0·117	+ 6·300
25	1	1·000	+0·987	0·000	+0·322	+0·165	+0·265	− 4·700
26	1	1·000	+0·926	0·000	+0·707	+0·391	+0·435	− 7·300
27	1	1·000	+0·874	0·000	+0·863	+0·511	+0·762	+15·700
28	1	1·000	+0·865	0·000	+0·882	+0·528	+0·456	−17·000
29	1	1·000	+0·803	0·000	+0·974	+0·633	+0·786	+ 3·100
30	1	1·000	+0·525	0·000	+0·915	+0·925	+1·390	−13·800
31	1	1·000	+0·320	0·000	+0·621	+1·039	+1·042	−22·100
32	1	1·000	+0·011	0·000	+0·023	+1·110	+1·667	− 4·600
33	1	1·000	+0·000	+0·655	+1·011	−0·814	−1·037	−19·100
34	1	1·000	0·000	+0·708	+1·020	−0·757	−1·249	−16·800
35	1	1·000	0·000	+0·767	+1·002	−0·683	−0·958	+ 5·600
36	1	1·000	0·000	+0·852	+0·906	−0·551	−0·636	− 6·300
37	1	1·000	0·000	+0·986	+0·338	−0·173	−0·244	−11·300
38	1	1·000	0·000	+1·000	−0·024	+0·012	+0·019	+ 0·200
39	1	1·000	0·000	+0·983	−0·358	+0·180	+0·232	+ 2·800
40	1	1·000	0·000	+0·941	−0·631	+0·326	+0·258	−13·700
41	1	1·000	0·000	+0·938	−0·648	+0·336	+0·478	− 8·400
42	1	1·000	0·000	+0·902	−0·774	+0·414	+0·486	− 2·000
43	1	1·000	0·000	+0·703	−0·985	+0·662	+0·947	−30·700
44	½	1·000	0·000	+0·591	−0·937	+0·743	+0·411	−55·500
45	½	1·000	0·000	−0·248	+0·470	+0·877	+1·055	+42·600
46	1	1·000	0·000	−0·462	+0·803	+0·810	+1·386	+20·000
47	1	1·000	0·000	−0·612	+0·951	+0·730	+0·608	+20·800
48	1	1·000	0·000	−0·639	+0·967	+0·711	+0·862	−10·000
49	1	1·000	0·000	−0·826	+0·921	+0·533	+0·582	− 6·500
50	1	1·000	0·000	−0·870	+0·850	+0·470	+0·691	+ 4·200
51	1	1·000	0·000	−0·951	+0·587	+0·301	+0·293	−11·500
52	1	1·000	0·000	−0·975	+0·429	+0·216	+0·292	− 3·300
53	1	1·000	0·000	−0·996	−0·188	−0·095	−0·117	+ 7·800
54	1	1·000	0·000	−0·987	−0·322	−0·165	−0·265	−16·900
55	1	1·000	0·000	−0·926	−0·707	−0·391	−0·435	+ 6·800
56	1	1·000	0·000	−0·874	−0·863	−0·511	−0·762	−10·200
57	1	1·000	0·000	−0·865	−0·882	−0·528	−0·456	− 2·400
58	1	1·000	0·000	−0·803	−0·974	−0·633	−0·786	− 5·100
59	1	1·000	0·000	−0·525	−0·915	−0·925	−1·390	+27·900
60	1	1·000	0·000	−0·320	−0·621	−1·039	−1·042	+15·700

From these observation equations the following normal equations were obtained in the usual way:—

$$
\begin{array}{lllllll}
+59{\cdot}000x & +\ 1{\cdot}942y_1 & -\ 2{\cdot}024y_2 & +\ 0{\cdot}105u & -\ 2{\cdot}404v & -\ 1{\cdot}283w & -116{\cdot}050=0 \\
 & +18{\cdot}321 & +\ 0{\cdot}000 & -\ 0{\cdot}305 & -\ 0{\cdot}191 & -\ 0{\cdot}726 & -\ 60{\cdot}553 \\
 & & +18{\cdot}109 & +\ 0{\cdot}045 & -\ 0{\cdot}246 & -\ 0{\cdot}722 & -101{\cdot}190 \\
 & & & +32{\cdot}546 & +\ 4{\cdot}254 & +\ 4{\cdot}829 & +\ 74{\cdot}346 \\
 & & & & +22{\cdot}254 & +26{\cdot}971 & -\ 33{\cdot}067 \\
 & & & & & +32{\cdot}497 & -\ 18{\cdot}782
\end{array}
$$

The solutions of these normal equations gave the corrections:—

x	= + 2·389	whence	$\delta\gamma$ = +2·389
y_1	= + 2·819		δK_1 = +2·819
y_2	= + 5·709		δK_2 = +5·709
u	= − 2·662		δe = −0·020
v	= +11·973		δT = +0·1812
w	= − 7·946		δP = −0·01515

and hence we get from the preliminary elements the final elements with their probable errors.

TABLE III.—ELEMENTS OF ζ_2 CORONAE BOREALIS

	Element	Preliminary	Final
γ	Velocity of System	− 32·0 km./sec.	− 29·61 ± 1·80 km./sec.
K_1	Semi-amplitude primary	132·0 "	134·82 ± 3·19 "
K_2	Semi-amplitude secondary	132·0 "	137·71 ± 3·20 "
ω_1	Longitude of apse primary	90°	90°
ω_2	Longitude of apse secondary	270°	270°
e	Eccentricity	0·05	0·030 ± ·0183
T	Time of periastron	J.D. 3,855·500	3,855·681 ± 0·158
P	Period	12·60 days	12·58485 ± 0·1578 days

From these elements are readily deduced

$a_1 \sin i$ = 23,310,000 km.
$a_2 \sin i$ = 23,820,000 km.
$m_1 \sin^3 i$ = 13·35⊙
$m_2 \sin^3 i$ = 13·06⊙

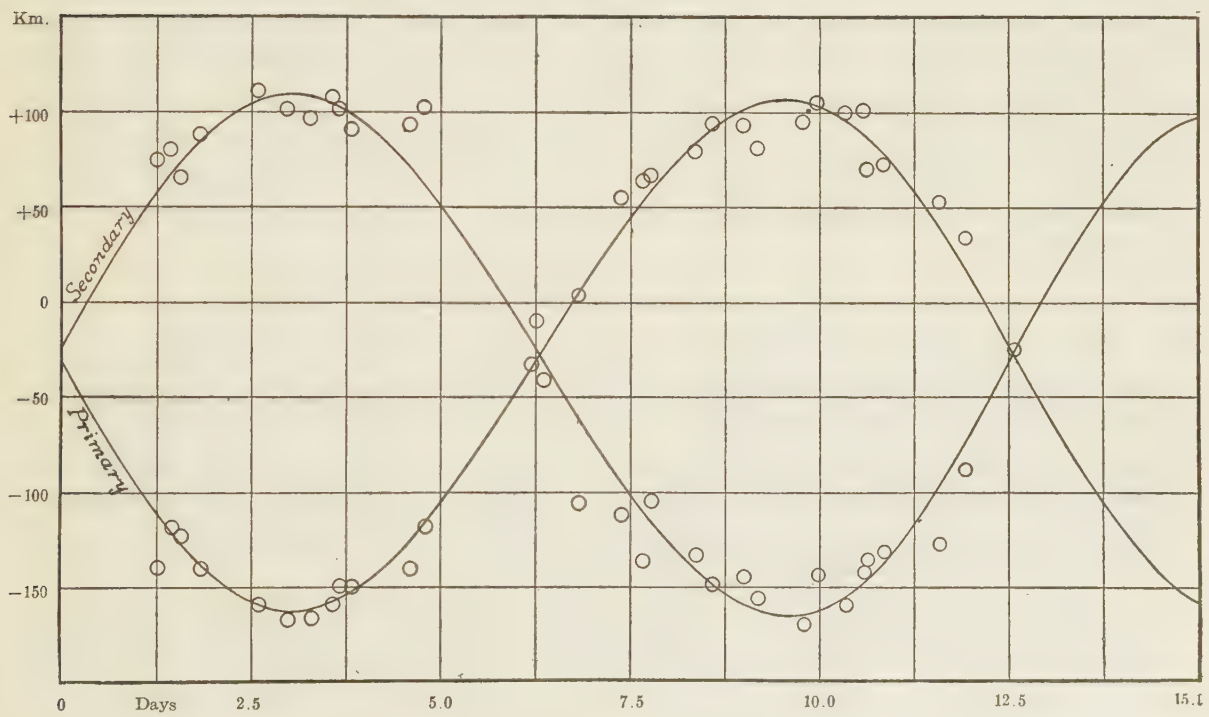

Fig. 1—Velocity Curve of ζ_2 Coronae Borealis.

The solution reduces Σpv^2 from 11490 to 9970. The probable error of a single plate of the brighter component is $\pm 11 \cdot 8$ and of the fainter $\pm 15 \cdot 1$ km. per second. The accompanying graph (Fig. 1) shows the final velocity curves with the observations plotted as circles.

The masses are unusually high for a star of this type and are not certainly exceeded by any other B8 stars with the possible exceptions of μ Sagittarii whose mass function is $3 \cdot 6 \odot$, but the spectrum of μ Sagittarii and also of υ Sagittarii and β Lyrae with masses of the same order can hardly be called of the normal B8 type. It will be of interest to compute the absolute magnitude and the parallax of this star from the known minimum mass by the various methods employed previously.* It seems likely that this star is in the giant stage and the probable density according to Seares'† statistical values would be about $\cdot 015$ while the temperature according to the most recent work would be about 12,000°. The absolute visual magnitude of the brighter component of ζ_2 Coronae Borealis which has an apparent magnitude of $5 \cdot 82$ is by Eddington's method $-3 \cdot 4$. The most probable value of the surface brightness of a B8 star is $-3 \cdot 0$ magnitudes which with a mass $13 \cdot 4$, density $\cdot 015$, gives an absolute magnitude of $-3 \cdot 0$. Taking the mean of these two values $-3 \cdot 2$ with apparent magnitude $5 \cdot 8$ gives a parallax of $0'' \cdot 0016$ or an approximate distance of 2,000 light years. This computed distance is the minimum value as it was obtained from conservative values of density and surface luminosity and with minimum values of the mass. The proper motion of this star according to Boss is $0'' \cdot 0135$ corresponding to a linear tangential velocity of 40 km. per second which combined with a radial velocity of 30 will give a space velocity of 50 km. per second.

The star is a visual double having a sixth magnitude companion $6'' \cdot 2$ distant in position angle 300°. According to Burnham the separation and position angle have remained unchanged for over 50 years with a common proper motion as above stated of $0'' \cdot 0135$. The visual component is of type B5 with moderately sharp lines and constant radial velocity, from seven plates, of -20 km. per second as compared with -30 for the star under discussion. From the fixity of position, from the difference in radial velocity and from the fact that, with a parallax of $0'' \cdot 0016$, the minimum separation is 4,000 astronomical units, it seems unlikely that there can be any orbital connection between the visual pair.

The Orbit of H.D. 25833

The binary character of this star, R.A. 4h. 0·6m., Dec. +33° 11′, vis. mag. 6·61, type B3, was discovered from the first plate obtained by the writer on September 10, 1924, which had a double lined spectrum with a relative separation of 314 km. Plates were consequently obtained at as frequent intervals as possible through the fall and winter, the total number being twenty-seven. All these plates were measured but three were not used in the determination of the orbit owing to their position with respect to the crossing points and the resultant blending of the doubled lines.

The spectrum is of type B3 with rather ill-defined lines which are, however, of better quality than in the preceding star as indicated by the probable error of an average plate of $+5 \cdot 1$ km. per sec. Nevertheless the spectra are difficult to measure on account of the

*This Pub. II, p. 328. †Mt. W. Cont. X, p. 404.

doubling and the measures of the fainter component especially are uncertain as indicated by the probable error of $\pm 13 \cdot 3$ km. per second. The maximum number of lines measured in any plate was 11 and the average number 8. The lines measured in the spectra of this star comprise hydrogen, Hβ, Hγ, Hδ, Hϵ; helium 4922, 4713, 4471, 4388, 4143, 4120, 4026, 4009; ionized magnesium 4481, carbon 4267, calcium 3933. Of the 24 observations used in the determination of the orbit all but the first two with the medium-focus camera were made with the short-focus triplet camera which is being principally used in the investigation of the B-type stars, giving a linear dispersion at Hγ of 49 A to the millimetre. The plates were measured on the Gaertner comparator with binocular eyepiece. In about half of them the measures were repeated and the velocity used is the simple mean in every case. The observations arranged in order of phase from periastron with their Julian dates, final phases, mean velocities and residuals are given in Table IV and are represented by circles in the accompanying graph (Fig. 2) of the final velocity curve.

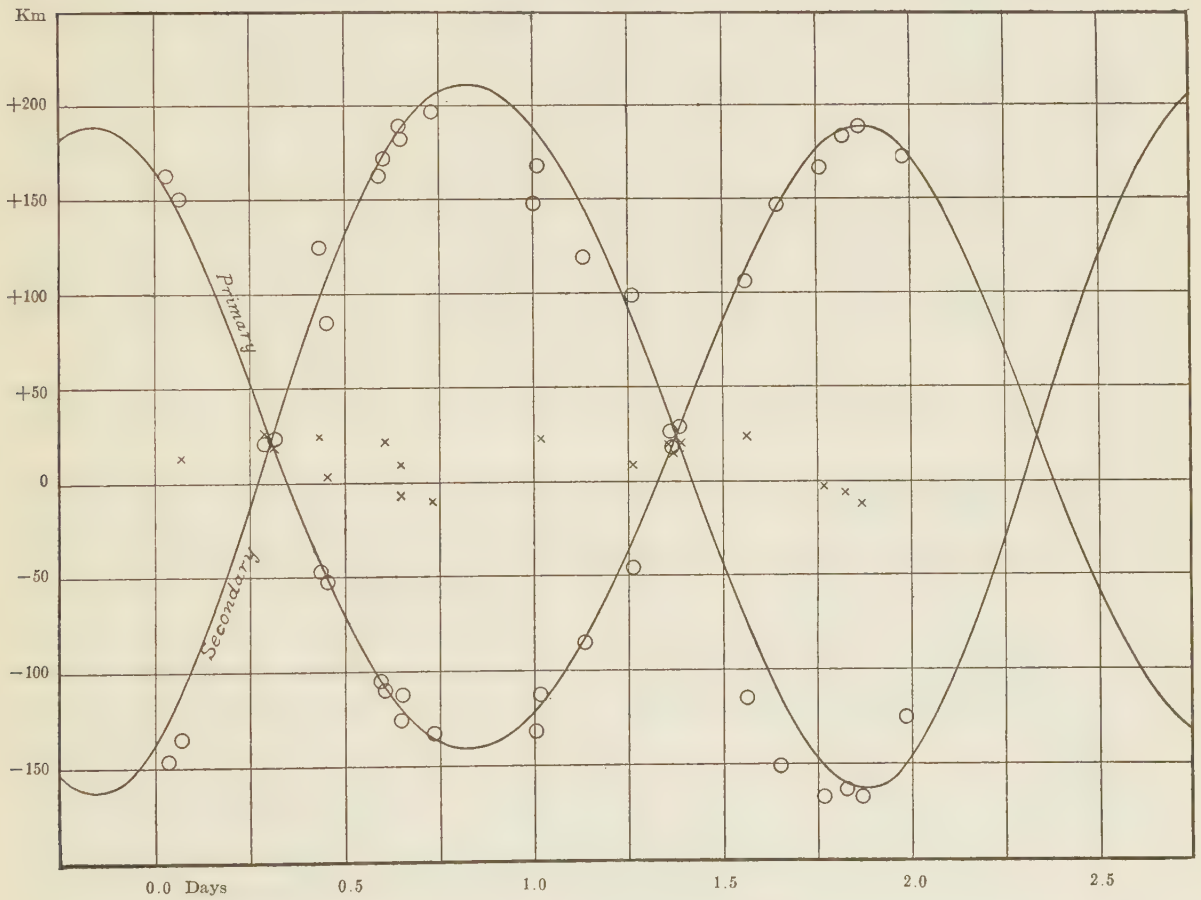

Fig. 2—Velocity Curve of H. D. 25833.

TABLE IV.—OBSERVATIONS OF H.D. 25833

Plate Number	Julian Date	Final Phase	Velocities Brighter Comp.			Velocities Fainter Comp.			Vel. K
			Observed	Computed	O-C	Observed	Computed	O-C	
11084	4,142·828	·035	+162·5	+154·91	+ 7·59	−147·0	−126·46	−20·5	
11038	4,138·805	·070	+150·4	+142·09	+ 8·31	−135·4	−111·91	−23·5	+13·2
11002	4,124·826	·291	+ 20·4	+ 33·13	−12·73	.....	+ 11·82	+ 8·6	+25·8
10807	4,057·913	·321	+ 22·6	+ 16·91	+ 5·69	.....	+ 30·23	− 7·6	+19·4
10963	4,116·858	·437	− 47·4	− 42·49	− 4·91	+124·1	+ 97·68	+26·4	+23·9
10761	4,053·992	·457	− 52·5	− 51·88	− 0·62	+ 83·9	+108·34	−24·4	+ 2·3
10721	4,043·988	·596	−105·5	−105·81	+ 0·31	+162·1	+169·58	− 7·5	
11149	4,165·714	·607	−110·5	−109·12	− 1·38	+171·0	+173·34	− 2·3	+21·2
10679	4,039·985	·650	−126·1	−120·60	− 5·50	+188·0	+186·38	+ 1·6	+ 8·5
11184	4,175·903	·653	−112·8	−121·49	+ 8·69	+181·6	+187·19	− 5·6	− 3·8
11305	4,222·644	·737	−132·2	−136·31	+ 3·11	+196·0	+204·21	− 8·2	−10·6
11122	4,145·825	1·004	−132·6	−121·86	−10·74	+146·7	+187·78	−41·1	
11069	4,141·778	1·014	−113·0	−119·63	+ 6·63	+166·7	+185·28	−18·6	+22·3
11053	4,139·870	1·135	− 85·4	− 84·00	− 1·40	+117·9	+144·81	−26·9	
10837	4,064·942	1·264	− 46·5	− 31·95	−14·55	+ 97·9	+ 85·71	+12·2	+ 8·8
10999	4,119·812	1·362	+ 25·7	+ 13·94	+11·76	.....	+ 33·60	− 7·9	+19·8
10773	4,054·905	1·370	+ 17·2	+ 17·71	− 0·51	.....	+ 29·33	−12·1	+14·6
10797	4,056·951	1·387	+ 27·7	+ 26·12	+ 1·58	.....	+ 19·78	+ 7·9	+20·3
*11353	4,235·644	1·565	+105·7	+110·55	− 4·85	−115·9	− 76·09	−39·8	+24·1
11334	4,229·644	1·651	+145·5	+144·90	+ 0·60	−150·8	−115·09	−35·7	
11134	4,158·761	1·768	+166·1	+177·63	−11·53	−168·4	−152·26	−16·1	− 3·0
11233	4,215·619	1·826	+182·6	+185·88	− 3·28	−163·8	−161·62	− 2·2	− 6·3
11303	4,221·749	1·870	+188·0	+188·10	− 0·10	−168·3	−164·15	− 4·1	−12·1
11117	4,144·777	1·984	+171·7	+176·82	− 5·12	−125·9	−151·34	+25·4	

*No. 11353 was obtained after the orbit was completed to fill in a gap in the curve and was obviously not included in the solution.

Considerable difficulty was experienced in obtaining the period of this binary, probably owing to its near approach to an integral number of days and it was only after nearly all the observations were made and several trials that a suitable period was found. However, there can be no doubt of its correctness and with this period of 2·0285 days the observations were plotted and preliminary elements, given in Table VI, were determined by the usual method of trial and error. A correction to these elements was carried through by Schlesinger's* method for the velocity of the system γ, the semi-amplitude K, the eccentricity e, the longitude of the apse ω, and the period P. On account of the small eccentricity both ω and T (the time of periastron) are indeterminate and the latter was omitted from the solution. Owing to the uncertainty of the measures of the secondary it was deemed preferable to determine the elements of the orbit from the primary alone, and after these were obtained, to determine the amplitude of the secondary considering the other elements as fixed.

Observation equations, Table V, were computed using the notation and methods of Schlesinger except for the period where the coefficients were further divided by 100 to make them homogeneous with those of the other unknowns. Owing to the correction for

*Pub. All. Obs. I, p. 33.

the period it was necessary to treat each observation separately and further owing to unequal quality the observations were each weighted in conformity with the general quality of the plate, the number of lines measured and the inter-agreement of these measures.

TABLE V.—OBSERVATION EQUATIONS

Number	Wt.	Γ	κ	π	ϵ	m	
1	·6	1·000	+·791	+·612	+·076	+63·2	= +11·51
2	·7	1·000	+·714	+·700	+·162	+69·3	+11·81
3	·6	1·000	+·054	+·998	+·766	+81·6	−10·94
4	·8	1·000	−·035	+·999	+·807	+17·6	+ 5·85
5	·5	1·000	−·403	+·915	+·825	+65·0	− 4·43
6	·6	1·000	−·452	+·892	+·806	+11·9	− 1·49
7	·8	1·000	−·779	+·627	+·524	+ 2·5	− 1·38
8	·6	1·000	−·808	+·589	+·481	+64·8	− 1·65
9	1·0	1·000	−·870	+·494	+·380	+ ·2	− 7·31
10	·4	1·000	−·882	+·472	+·357	+55·4	+ 7·94
11	·8	1·000	−·971	+·240	+·148	+37·0	+ 2·05
12	·4	1·000	−·875	−·485	−·007	−42·2	−12·98
13	·6	1·000	−·861	−·509	+·005	−42·6	+ 4·35
14	·5	1·000	−·642	−·766	+·231	−63·4	− 3·49
15	·5	1·000	−·331	−·944	+·545	−20·3	−15·18
16	·8	1·000	−·045	−·999	+·750	−69·0	+10·54
17	·6	1·000	−·031	−1·000	+·758	−13·4	− ·33
18	·8	1·000	+·021	−1·000	+·783	−15·2	+ 1·76
19	·6	1·000	+·755	−·656	+·566	−116·9	+ ·38
20	·6	1·000	+·942	−·335	+·234	−38·6	− 9·51
21	0·4	1·000	+·990	−·142	+·081	−24·5	− ·56
22	1·0	1·000	+1·000	+·008	−·004	+ 1·5	+ 3·00
23	·6	1·000	+·926	+·377	−·048	+39·7	− 1·31

From these observation equations the following normal equations were obtained:—

$$
\begin{array}{rrrrrr}
14{\cdot}800\Gamma & -1{\cdot}024\kappa & +1{\cdot}007\pi & +6{\cdot}068\epsilon & +\cdot444m & =-0{\cdot}150 \\
 & +7{\cdot}434 & -\cdot691 & -1{\cdot}199 & -\cdot287m & =+18{\cdot}211 \\
 & & +7{\cdot}366 & +\cdot424 & +3{\cdot}928m & =+3{\cdot}910 \\
 & & & +3{\cdot}886 & +\cdot072m & =-2{\cdot}822 \\
 & & & & +3{\cdot}545m & =+5{\cdot}155
\end{array}
$$

The solution of these normal equations gave the following values to the unknowns and corrections to the elements:—

$\Gamma = +\cdot3038$ whence $\delta\gamma = +\cdot377$ km.
$\kappa = +2{\cdot}4682$ $\delta K = +2{\cdot}468 \pm 1{\cdot}89$ km.
$\pi = -\cdot2933$ $\delta\omega = +\cdot001805 = +0°{\cdot}103 \pm 1°{\cdot}00$
$\epsilon = -\cdot4433$ $\delta e = +\cdot00123 \pm \cdot0102$
$m = +1{\cdot}9494$ $\delta\mu = -\cdot000111$ or
$\delta\rho = +\cdot00008 \pm \cdot00118$ days

The preliminary and final elements follow in Table VI.

TABLE VI.—ELEMENTS OF H.D. 25833

Element	Preliminary	Final
Period	P 2·0285 days	2·02858 ± ·00118 days
Eccenticity	e 0·05	0·0512 ± ·0102
Longitude of apse	ω 30°·0	30°·103 ± 1°·00
Time of periastron	T J.D. 4039·335	4039·335
Semi-amplitude primary	K_1 162·5 km.	164·97 ± 1·89 km.
Semi-amplitude secondary	K_2 190·0 "	187·32 ± 6·1 "
Velocity of system	γ +15·46 "	+15·84 km.

From these follow at once:—

$$a_1 \sin i = 4{,}549{,}000 \text{ km.}$$
$$a_2 \sin i = 5{,}165{,}000 \text{ km.}$$
$$m_1 \sin^3 i = 4{\cdot}86\odot$$
$$m_2 \sin^3 i = 4{\cdot}29\odot$$

By similar methods to those used in the previous star with the assumptions of a temperature of 15000°K, a surface brightness of −3·3 magnitudes and a density of 0·1 for a B3 star, we get by Eddington's method, an absolute magnitude of −1·6 for the brighter component, and by computation from mass, density and surface brightness, −1·4. The mean value −1·5 absolute magnitude for the brighter component whose apparent magnitude will be about 7·4 gives a hypothetical parallax of 0″·00166, equivalent to a distance of 600 parsecs or nearly 2,000 light years, practically identical with ζ_2 Coronae. As in the case of the latter this distance is a minimum value and, with the doubled distance of H.D. 216014 obtained by Mr. Pearce, places these B-type stars considerably further away than usually accepted.

The K line of ionized calcium was measured in 18 plates of this star and the measures are represented by crosses on the velocity curve (Fig. 2). The line is very weak and difficult generally and the measures are uncertain. Although there is a total range of some 35 km. in the velocity with some indication of orbital effect, the latter is decidedly uncertain, and the mean calcium velocity +10·5 km. does not differ much from the solar component of +7·1 km. nor indeed from the velocity of the system +15·8 km. Type B3 appears to be about the lower limit of temperature which will produce excitation in interstellar calcium and the effect hence appears to be present in this example with a possible influence due to stellar calcium.

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THE ORBITS OF FIVE SPECTROSCOPIC BINARIES

BY W. E. HARPER

The stars whose orbits are determined are given in the following table.

Star	α 1900	δ 1900	Vis. Mag.	Type
	h m	° ′		
45 Aurigae	6 13·7	+53 30	5·41	F5
19 Leo Minoris	9 51·6	41 32	5·19	F4
105 Herculis	18 15·1	24 24	5·49	K5
22 Vulpeculae	20 11·2	23 12	5·38	G7
π Cephei	23 04·7	+74 51	4·56	G5

45 AURIGAE

Abstract.—Twenty-eight spectrograms of single-prism dispersion and measured on the spectrocomparator against Procyon as a standard serve to determine the orbital elements. Early Lick observations assist in fixing the period at 6·5013 days. The eccentricity is ·019.

This star (1900 $\alpha = 6^h\ 13^m.7$, $\delta = +53°\ 30'$) whose visual magnitude is 5.41 and type F5, was announced as a spectroscopic binary by Campbell in the *Publications of the Astronomical Society of the Pacific* for June, 1922.

Twenty-eight spectrograms obtained with the single-prism spectrograph whose dispersion at Hγ is 29 angstroms per millimetre, were made during 1922, 1923, 1924 and 1925, and these form the basis of the determination of the orbit. The plates of 1923,

April 2, and 1924, April 7, were given half weight, as in the former a very narrow spectrum was secured and in the latter the focus was not of the best. Further, the plate of 1924, November 22, has not been used at all in the determination, owing to the fact that a few minutes' exposure of an A-type star was accidentally made on the same plate.

The spectrum contains numerous well-defined lines due principally to iron, titanium, manganese, chromium and calcium. On one plate, number 8541, there were measured 153 lines between λ3941 and λ4600. By selecting a plate of different exposure other lines could be measured and the total increased. In the list given in *Harvard Annals*, Volume 28, page 79, which lists the lines in stars of division c, there are 183 recorded between the same limits. The great majority, though not all, of the 153 measured in this star are found in that particular list.

Through the kindness of the Lick observers the data of their seven observations were furnished, and for convenience of reference these are tabulated here. All their plates were made with the three-prism Mills spectrograph and should be very reliable. The plates have assisted materially in fixing the period accurately, but otherwise have not been made use of in the determination. A systematic difference of −3.67 km. has been added to each velocity before the residuals as shown were obtained. Our own plates were measured on the spectrocomparator against the standard plate of Procyon, number 3375, and the velocities deduced are given in the table following. The tables list the phases of the observations as based upon the final elements, and the residuals from the final curve are given in the last column. The determination does not appear wholly satisfactory, as the probable error of a plate is ±1.89 km. per sec., larger than one might expect from single-prism plates when the character of the spectrum is considered. In the final curve the way the observations fall above and below the curve around the γ-point is suggestive of the presence of the spectrum of the second component. The last observation was made on a fine-grained plate to see if the fainter spectrum could be recorded, but no certain evidence was obtained.

LICK OBSERVATIONS OF 45 AURIGAE

Plate Number	Date	Julian Date	Phase	Velocity	Lines	O–C
9503	1917 Nov. 1	2,421,534·036	6 291	+24·35	30	−2·14
10507	1919 Jan. 25	1,984·866	2·030	+ 3·60	32	−1·85
10901	Sept. 25	2,227.948	4·564	−19·43	31	+1·75
10934	Oct. 11	2,243·942	1·054	+31·86	30	+1·94
10992	Nov. 10	2,273·047	4·154	−27·64	31	−0·20
11030	Nov. 24	2,287·052	5·156	− 6·65	30	−0·58
11082	Dec. 29	2,422,322·935	2·032	+ 6·58	27	+1·19

VICTORIA OBSERVATIONS OF 45 AURIGAE

Plate Number	Date	Julian Date	Phase	Velocity	Wt.	O–C
8348	1922 Nov. 11	2,423,370·963	3·350	−31·2	1	−1·5
8495	1923 Jan. 10	3,430·865	4·741	−19·0	1	+2·0
8536	" 28	3,448·782	3·154	−29·6	1	−2·6
8541	" 31	3,451·754	6·126	+19·9	1	+0·6
8578	Feb. 24	3,475·780	4·147	−27·3	1	+3·7
8603	" 26	3,477·764	6·131	+23·0	1	+3·6
8637	Mar. 2	3,481·770	3·635	−32·4	1	0·0
8677	" 19	3,498·695	1·056	+24·4	1	−1·8
8722	" 26	3,505·728	1·588	+12·8	1	−1·4
8723	" 26	3,505·745	1·605	+11·9	1	−1·9
8762	" 30	3,509·771	5·631	+ 5·3	1	+0·3
8775	April 2	3,512·653	2·012	+ 6·6	½	+4·4
8776	" 2	3,512·666	2·025	+ 6·2	½	+4·2
8808	" 9	3,519·719	2·576	−18·7	1	−5·0
8809	" 9	3,519·732	2·589	−16·6	1	−2·3
9706	1924 Mar. 3	3,848·702	6·494	+28·8	1	+2·2
9721	" 10	3,855·721	·511	+32·9	1	+2·1
9742	" 14	3,859·712	4·502	−26·3	1	−0·3
9828	April 7	3,883·681	2·466	− 5·5	½	+5·2
9829	" 7	3,883·708	2·493	− 3·4	½	+8·1
10859	Oct. 10	4,069·020	5·768	+ 6·4	1	−2·6
10942	Nov. 22	4,112·908	4·147	−24·5		
11101	Dec. 23	4,143·918	2·651	−14·2	1	+1·5
11175	1925 Jan. 23	4,174·794	1·020	+25·3	1	−1·4
11214	Feb. 14	4,196·730	3·452	−33·5	1	−2·3
11226	" 24	4,205·734	5·955	+10·0	1	−4·4
11260	Mar. 6	4,216·730	3·948	−33·0	1	−0·5
11320	" 16	2,424,226·702	·918	+28·0	1	−0·2

From the first few plates it was seen that the period was in the neighbourhood of 6·5 days. Our later observations defined this more closely and with the aid of the Lick results a definite value of 6·5013 days was established. Preliminary elements were then adopted as follows.

Preliminary Elements

$P = 6{\cdot}5013$ days
$e = {\cdot}04$
$\omega = 354°$
$K = 32{\cdot}3$ km.
$\gamma = -0{\cdot}7$ km.
$T = $ J.D. 2,423,634·597

The observations were grouped into 16 normal places and observation equations were built up according to the usual Lehman-Filhés form, connecting the residuals with the elements K, e, ω and T. In these equations

$x = \delta\gamma$
$y = \delta K$
$z = K \cdot \delta e$
$u = K \cdot \delta\omega$
$v = 31{\cdot}292\ \delta T$

NORMAL PLACES

	Mean Phase	Mean Velocity	Wt.	O–C Prel.	O–C Final		Mean Phase	Mean Velocity	Wt.	O–C Prel.	O–C Final
1	1·038	+24·85	2	−3·7	−1·66	9	4·502	−26·30	1	−0·8	−0·28
2	1·597	+12·40	2	−3·0	−1·92	10	4·741	−19·00	1	+1·6	+2·01
3	2·019	+ 6·40	1	+3·8	+4·47	11	5·631	+ 5·30	1	+0·5	+0·34
4	2·479	− 4·20	1	+7·0	+6·97	12	5·861	+ 8·20	2	−3·8	−3·64
5	2·605	−16·50	3	−1·8	−1·81	13	6·129	+21·40	2	+1·7	+2·29
6	3·252	−30·40	2	−2·5	−1·74	14	6·494	+28·80	1	+0·9	+2·23
7	3·543	−32·95	2	−2·0	−1·09	15	·511	+32·90	1	0·0	+2·14
8	4·047	−30·15	2	+0·8	+1·74	16	·918	+28·00	1	−2·3	−0·19

OBSERVATION EQUATIONS

1	1·000x	+ ·904y	+ ·389z	+ ·499u	+ ·537v	+3·7 = 0
2	1·000	+ ·497	− ·679	+ ·885	+ ·914	+3·0
3	1·000	+ ·101	−1·002	+ ·994	+ ·994	−3·8
4	1·000	− ·326	− ·644	+ ·926	+ ·897	−7·0
5	1·000	− ·433	− ·450	+ ·877	+ ·843	+1·8
6	1·000	− ·843	+ ·648	+ ·466	+ ·435	+2·5
7	1·000	− ·934	+ ·939	+ ·223	+ ·209	+2·0
8	1·000	− ·936	+ ·856	− ·224	− ·203	−0·8
9	1·000	− ·767	+ ·211	− ·595	− ·556	+0·8
10	1·000	− ·617	− ·227	− ·758	− ·719	−1·6
11	1·000	+ ·170	− ·946	− ·995	−1·010	−0·5
12	1·000	+ ·394	− ·695	− ·939	− ·970	+3·8
13	1·000	+ ·631	− ·219	− ·811	− ·852	−1·7
14	1·000	+ ·885	+ ·511	− ·538	− ·574	−0·9
15	1·000	+1·040	+ ·998	− ·025	− ·023	0·0
16	1·000	+ ·959	+ ·602	+ ·390	+ ·422	+2·3

From these were formed the normal equations

$$
\begin{array}{rrrrrrrrrrr}
25{\cdot}000x & - & {\cdot}428y & + & {\cdot}631z & + & 2{\cdot}228u & + & 2{\cdot}100v & + & 19{\cdot}700 = 0 \\
 & & 12{\cdot}613 & - & 2{\cdot}668 & - & 1{\cdot}479 & - & 1{\cdot}419 & + & 5{\cdot}328 \\
 & & & & 10{\cdot}991 & - & {\cdot}367 & - & {\cdot}256 & + & 7{\cdot}712 \\
 & & & & & & 12{\cdot}287 & + & 12{\cdot}338 & + & 5{\cdot}291 \\
 & & & & & & & & 12{\cdot}405 & + & 5{\cdot}513
\end{array}
$$

from which there resulted the corrections as follows:

$$
\begin{aligned}
\delta\gamma &= -\ 0{\cdot}82 \text{ km.} \\
\delta K &= -\ 0{\cdot}56 \text{ km.} \\
\delta e &= -\ 0{\cdot}021 \\
\delta\omega &= -23^\circ{\cdot}40 \\
\delta T &= -\ 0{\cdot}431 \text{ days}
\end{aligned}
$$

The corrections for ω and T are large, but uncertainty in their determination is always present when the eccentricity is as low as in this case, resulting as it does in almost identical coefficients in the observation and normal equations for these two elements. Had either element been considered fixed, as is often done, the correction to the other would have been vanishingly small.

The sum of the squares of the residuals for the normal places was reduced from 184·5 to 156·6, or about 15 per cent, and satisfactory agreement existed between equation and ephemeris residuals.

Final Elements

$$
\begin{aligned}
P &= 6\cdot5013 \text{ days} \\
e &= \cdot019 \pm \cdot026 \\
\omega &= 330^\circ\cdot60 \pm 40^\circ\cdot85 \\
\gamma &= -1\cdot52 \text{ km.} \pm 0\cdot57 \text{ km.} \\
K &= 31\cdot74 \text{ km.} \pm 1\cdot08 \text{ km.} \\
T &= \text{J.D. } 2{,}423{,}634\cdot166 \pm 0\cdot741 \text{ day} \\
a \sin i &= 2{,}837{,}000 \text{ km.}
\end{aligned}
$$

The graph shown (Fig. 1) represents the final elements with the observations as grouped.

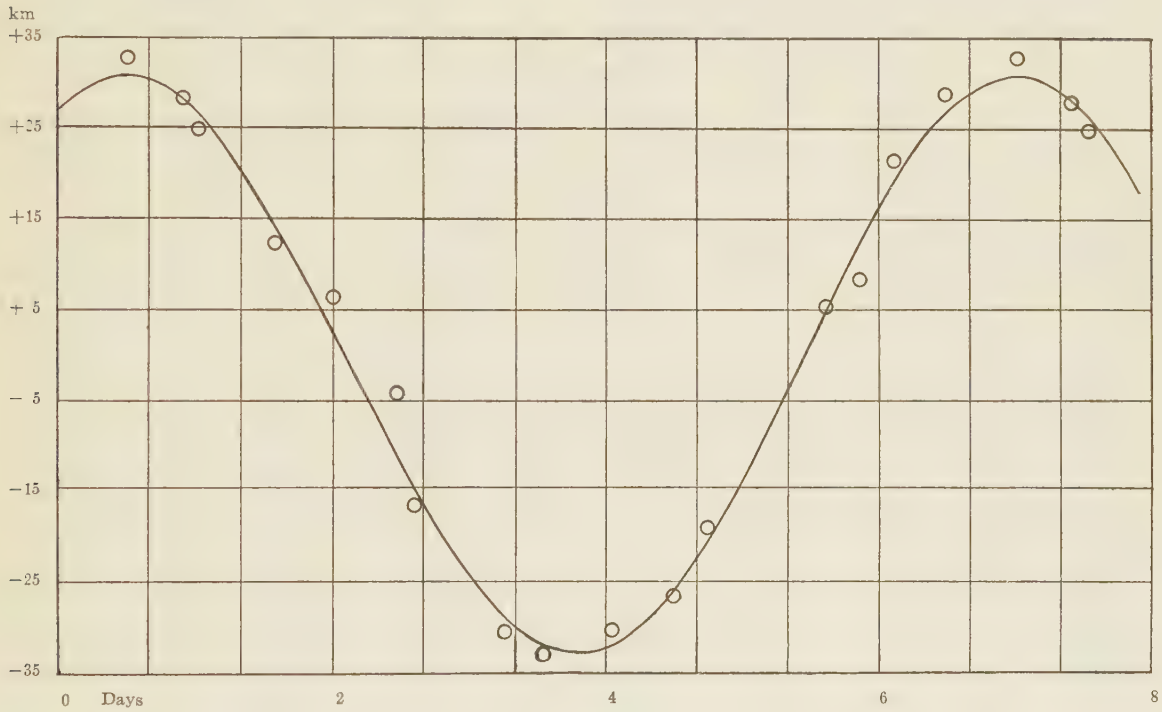

Fig. 1—Radial Velocity Curve of 45 Aurigae

In our absolute magnitude work we found from the ratios of six pairs of lines an absolute magnitude of +1·5 for this star corresponding to a prallax of 0″·016.

In the foregoing the dates are given in Greenwich Mean Time as used prior to 1925.

Dominion Astrophysical Observatory,
Victoria, B.C.

March, 1925.

2873—2½

19 LEO MINORIS

Abstract.—Thirty-three spectrograms of this star obtained in 1923, 1924 and 1925 with the single-prism spectrograph serve to determine the orbital elements. Its spectrum is F4 and the plates were measured on the spectrocomparator against Procyon as a standard. The probable error of a plate is ±1·2 km./sec. The period is 9·283 days and the eccentricity small.

The star 19 Leo Minoris, Boss 2665 (1900 $\omega = 9^h\ 51^m{\cdot}6$, $\delta = +41°\ 32'$), visual magnitude 5·19 and type F4, was noted to be a spectroscopic binary from the first two plates made in 1923. A total of 33 plates have been obtained with the single-prism spectrograph, and these serve as the basis for the determination of the orbital elements. The lines of the F4 spectrum are well defined and the plates were measured against Procyon on the spectrocomparator. As the star is bright the plates are all well exposed and, while two are slightly inferior to the rest, they have all been weighted equally in the solution. The probable error of a plate on the basis of the final elements is ± 1·2 km./sec. and is quite satisfactory.

OBSERVATIONS OF 19 LEO MINORIS

Plate Number	Date	Julian Date	Phase	Velocity	Residual O–C
8680	1923 Mar. 19	2,423,498·773	·178	+ 6·2	+0·4
8702	" 24	3,503·779	5·184	−25·3	−0·2
8726	" 26	3,505·796	7·201	−11·7	−0·2
8779	April 2	3,512·717	4·839	−26·5	−1·3
8811	" 9	3,519·763	2·602	−11·7	+0·1
8866	" 23	3,533·725	7·281	− 9·9	+0·6
8943	May 7	3,547·694	2·684	−14·1	−1·4
8977	" 22	3,562·716	8·423	− 0·9	−1·3
9709	1924 Mar. 3	3,848·843	6·777	−15·3	+0·4
9725	" 10	3,855·839	4·490	−26·6	−1·8
9744	" 14	3,859·780	8·431	+ 0·1	−0·4
9767	" 17	3,862·793	2·161	− 7·6	−0·1
9785	" 22	3,867·740	7·108	−11·7	+0·7
9799	" 24	3,869·780	9·148	+ 8·0	+3·3
9813	" 28	3,873·795	3·880	−22·8	−0·4
9831	April 8	3,884·765	5·567	−24·4	−0·4
9838	" 14	3,890·737	2·256	− 6·6	+1·8
9850	" 21	3,897·758	9·277	+ 5·6	+0·5
9935	May 9	3,915·693	8·646	− 1·2	−3·5
9978	" 19	3,925·705	·092	+ 3·4	−2·1
10008	" 23	3,929·700	4·087	−26·0	−2·5
10055	June 2	3,939·705	4·809	−22·9	+2·4
10108	" 16	3,953·724	·262	+ 8·0	+2·5
10164	" 26	3,963·722	·977	− 0·8	−3·6
11105	Dec. 24	4,144·008	4·886	−27·3	−2·0
11141	1925 Jan. 9	4,160·955	3·267	−14·7	+3·5
11185	" 24	4,174·964	7·993	− 2·6	+0·6
11263	Mar. 6	4,216·775	3·389	−17·7	+1·4
11310	" 14	4,224·840	2·171	− 8·6	−1·0
11323	" 16	4,226·799	4·130	−23·1	+0·6
11346	" 22	4,232·912	·960	+ 1·7	−1·3
11388	" 30	4,240·851	8·899	+ 4·6	+0·9
11415	April 6	2,424,247·661	6·426	−16·7	+2·0

The period was quite early seen to be about 9·3 days, and a value of 9·283 was established from the first two years' observations. It has not been necessary to change this for the 1925 series. The preliminary elements adopted from graphical methods follow.

PRELIMINARY ELEMENTS

$P = 9{\cdot}283$ days
$e = {\cdot}10$
$\omega = 345°$
$\gamma = -10{\cdot}75$ km.
$K = 16{\cdot}0$ km.
$T =$ J.D. 2,423,498·500

The observations were grouped into 17 normal places and observation equations built up in the usual way connecting the elements with the residuals for the normal places.

NORMAL PLACES

	Mean Phase		Mean Velocity	Wt.	Residual O–C	
	Prel.	Final			Prel.	Final
1	8·994	8·899	+ 4·6	1	−0·2	+0·9
2	·079	9·267	+ 5·7	3	−0·8	+0·7
3	·315	·220	+ 7·1	2	+0·3	+1·9
4	1·064	·969	+ 0·4	2	−3·6	−2·5
5	2·291	2·196	− 7·6	3	+0·3	+0·3
6	2·738	2·643	−12·9	2	−0·4	−0·4
7	3·423	3·328	−16·2	2	+2·3	+2·5
8	4·127	4·032	−24·0	3	−1·2	−0·8
9	4·585	4·490	−26·6	1	−2·1	−1·8
10	4·940	4·845	−25·6	3	−0·5	−0·3
11	5·279	5·184	−25·3	1	−0·2	−0·2
12	5·662	5·567	−24·4	1	0·0	−0·4
13	6·521	6·426	−16·7	1	+3·3	+2·0
14	7·038	6·943	−13·5	2	+2·1	+0·5
15	7·336	7·241	−10·8	2	+1·7	+0·2
16	8·088	7·993	− 2·6	1	+1·2	+0·6
17	8·595	8·500	− 0·7	3	−2·3	−1·9

In the observation equations the following substitutions have been made in the Lehmann-Filhés coefficients.

$x = \delta\gamma$
$y = \delta K$
$z = K \cdot \delta e$
$u = K \cdot \delta\omega$
$v = 10{\cdot}994 . \delta T$

OBSERVATION EQUATIONS OF 19 LEO MINORIS

							Wt.
1	1·000x	+ ·974y	+ ·725z	− ·506u	− ·578v	+ 0·2 = 0	1
2	1·000	+1·078	+1·239	− ·220	− ·235	+ 0·8	3
3	1·000	+1·097	+ ·966	− ·026	000	− 0·3	2
4	1·000	+ ·920	+ ·064	+ ·542	+ ·644	+ 3·6	2
5	1·000	+ ·181	− ·998	+ ·970	+ ·961	− 0·3	3
6	1·000	− ·107	− ·759	+ ·953	+ ·893	+ 0·4	2
7	1·000	− ·482	− ·043	+ ·789	+ ·694	− 2·3	2
8	1·000	− ·756	+ ·681	+ ·496	+ ·427	+ 1·2	3
9	1·000	− ·860	+ ·949	+ ·263	+ ·234	+ 2·1	1
10	1·000	− ·899	+ ·996	+ ·068	+ ·076	+ 0·5	3
11	1·000	− ·899	+ ·903	− ·120	− ·077	+ 0·2	1
12	1·000	− ·854	+ ·640	− ·335	− ·259	0·0	1
13	1·000	− ·302	− ·853	− ·943	− ·890	− 2·1	2
14	1·000	− ·109	−1·013	−1·004	− ·989	− 1·7	2
15	1·000	+ ·434	− ·642	− ·968	−1·052	− 1·2	1
16	1·000	+ ·773	+ ·132	− ·763	− ·866	+ 2·3	3
17	1·000	− ·580	− ·321	− ·762	− ·670	− 3·3	1

From these there resulted the following normal equations:—

$$
\begin{array}{rrrrrrrrrrrr}
33{\cdot}000x & + & 1{\cdot}380y & + & 5{\cdot}128z & - & {\cdot}153u & - & {\cdot}609v & + & 6{\cdot}700 & = 0 \\
 & & 18{\cdot}061 & + & 1{\cdot}154 & - & 2{\cdot}799 & - & 2{\cdot}882 & + & 13{\cdot}026 & \\
 & & & & 21{\cdot}716 & - & {\cdot}234 & - & {\cdot}349 & + & 19{\cdot}376 & \\
 & & & & & & 14{\cdot}878 & + & 14{\cdot}723 & + & 7{\cdot}752 & \\
 & & & & & & & & 14{\cdot}696 & + & 7{\cdot}340 &
\end{array}
$$

which gave corrections as follows:—

$$
\begin{aligned}
\delta\gamma &= -\ {\cdot}03 \text{ km.} \\
\delta K &= -\ {\cdot}76 \text{ km.} \\
\delta e &= -\ {\cdot}052 \\
\delta \omega &= +\ 6^\circ{\cdot}09 \\
\delta T &= +\ {\cdot}095 \text{ days}
\end{aligned}
$$

The sum of the squares of the residuals for the normal places was reduced from 91·2 to 56·6 and satisfactory agreement existed between equation and ephemeris residuals, the numerical average being 0·04 km.

The final elements, then, with their probable errors are the following:

FINAL ELEMENTS

$$
\begin{aligned}
P &= 9{\cdot}283 \text{ days} \\
e &= {\cdot}048 \pm {\cdot}020 \\
\omega &= 351^\circ{\cdot}09 \pm 14^\circ{\cdot}95 \\
\gamma &= -10{\cdot}78 \pm 0{\cdot}26 \text{ km.} \\
K &= 15{\cdot}24 \pm 0{\cdot}35 \text{ km.} \\
T &= \text{J.D. } 2{,}423{,}498{\cdot}595 \pm 0{\cdot}383 \text{ day} \\
a \sin i &= 1{,}943{,}130 \text{ km.}
\end{aligned}
$$

The graph (Fig. 2) represents the final elements and the grouped observations are shown.

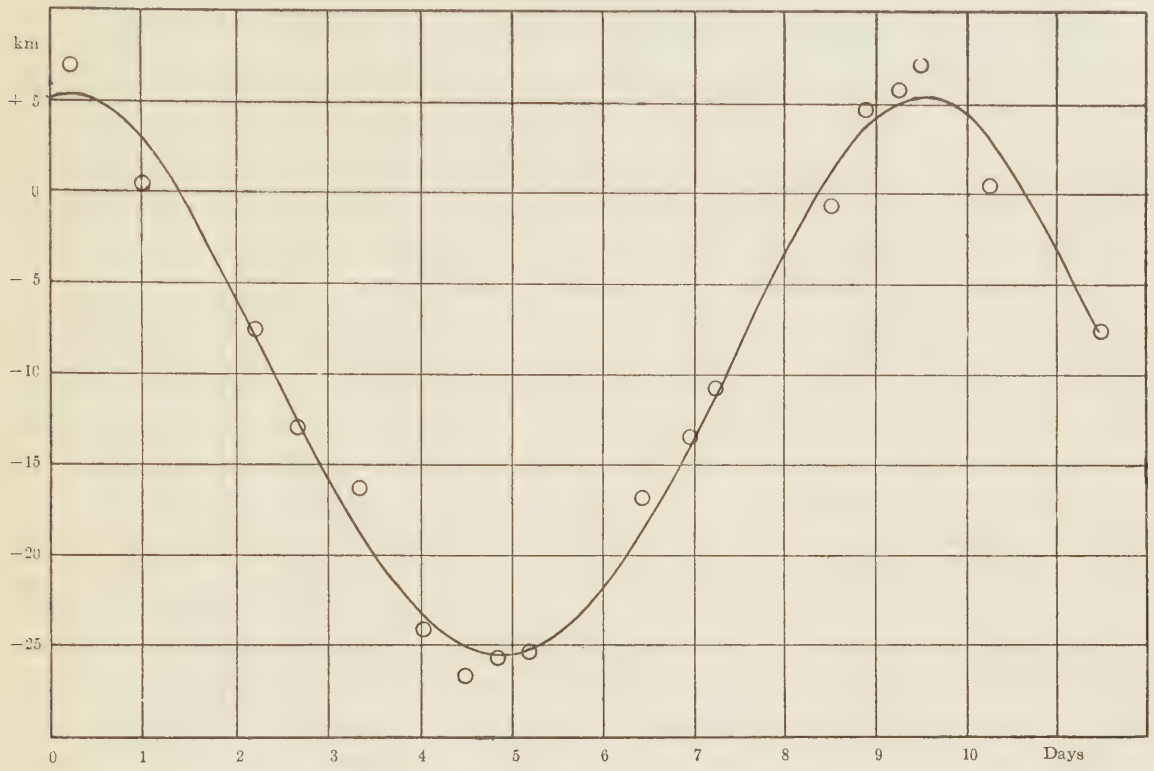

FIG. 2.—Radial Velocity Curve of 19 Leo Minoris

All times are expressed in Greenwich Mean Time as used prior to 1925.

Dominion Astrophysical Observatory,
Victoria, B.C.
April 10, 1925.

105 HERCULIS

Abstract.—Twenty-five spectrograms of this K-type star were obtained with the single-prism spectrograph since April, 1922, and upon these a solution of the orbit is based. The period adopted is 478 days, but this is uncertain to the extent of a few days, as the observations cover only two cycles. The eccentricity is ·398 with semi-amplitude 16·07 km./sec.

The star 105 Herculis (1900 $\alpha = 18^h\ 15^m{\cdot}1$, $\delta = +24°\ 24'$) whose visual magnitude is 5·49 and type K5, was first observed here on April 17, 1922. A total of 25 plates has been secured with the single-prism spectrograph and these serve as the basis for the determination of the orbit of this spectroscopic binary. In our parallax work we gave the type as K2, but the best exposed plate, made probably since that type was assigned, shows it to be closer to K5 which Harvard gives for the star.

The plates as a whole are much inferior to our average run and the writer accepts the responsibility for such being the case. The star seems unusually red and it so happened that on many of the nights when the star was observed it was more or less hazy, resulting in a weakened spectrum in the violet. The plates were measured on the spectrocomparator against Arcturus as a standard, and the velocities deduced with the weights assigned are given in the table of observations. The phases are based on the final value of periastron passage with the period 478 days and the residuals are scaled from the curve shown which represents the final elements. The elements are not to be considered as definite for, owing to the fact that only two cycles of the period are covered, the period must be uncertain to the extent of a few days. Observations will be taken here in future years to improve the value of the period and by means of which it is hoped to lessen the probable errors of the elements. These are rather high due to the probable error of a plate being $\pm 2{\cdot}0$ km. per second and also to the small range in velocity variation.

OBSERVATIONS OF 105 HERCULIS

Plate Number	Date	Julian Date	Phase	Velocity	Wt.	O–C
7470	1922 April 17	2,423,162·001	99·35	− 2·7	3	−0·7
7622	May 28	3,203·867	141·22	− 7·8	3	−5·0
8254	Oct. 27	3,355·650	293·00	−21·2	2	−7·0
8284	Nov. 2	3,361·625	298·98	−11·4	2	+2·7
8308	" 8	3,367·572	304·92	−11·4	3	+3·4
8709	1923 Mar. 25	3,504·007	441·36	−34·3	3	−0·3
8875	April 23	3,533·971	471·32	−26·6	3	+3·5
8950	May 7	3,547·906	7·26	−21·8	2	+2·3
8971	" 19	3,559·942	19·29	−19·5	3	−0·6
9026	June 6	3,577·891	37·24	−11·6	2	−1·0
9084	" 25	3,596·846	56·20	− 7·3	3	−1·6
9190	July 20	3,621·827	81·18	− 4·3	3	−1·6
9304	Aug. 17	3,649·742	109·09	− 0·7	3	+1·3
9493	Oct. 8	3,701·613	160·96	− 3·4	3	+0·2
9941	1924 May 9	3,915·937	375·29	−22·0	3	+2·1
10065	June 2	3,939·950	399·30	−28·3	3	−0·2
10198	" 30	3,967·895	427·24	−38·8	1	−6·0
10242	July 7	3,974·780	434·13	−34·1	3	−0·5
10534	Aug. 25	4,023·699	5·05	−21·6	3	+3·6
10634	Sept. 8	4,037·729	19·08	−23·7	3	−5·2
10906	Oct. 27	4,086·592	67·94	+ 0·1	3	+4·0
10908	" 31	4,090·587	71·94	− 2·8	3	+0·6
10944	Nov. 24	4,114·558	95·91	+ 3·4	2	+5·4
11430	1925 April 6	4,247·978	229·33	− 8·2	3	−0·2
11503	" 13	2,424,254·981	236·33	− 8·6	2	−0·3

NORMAL PLACES

—	Mean Phase Final	Mean Velocity	Wt.	O–C	
				Prel.	Final
1	102·14	−0·42	·8	+2·40	+1·62
2	151·09	5·60	·6	−2·18	−2·50
3	232·13	8·36	·5	− ·30	− ·10
4	299·82	14·20	·7	− ·17	+ ·15
5	375·29	22·00	·3	+1·94	+2·12
6	399·30	28·30	·3	− ·35	− ·22
7	436·24	34·86	·7	−1·72	−1·18
8	471·32	26·60	·3	+2·09	+3·47
9	13·16	21·64	1·1	−1·26	− ·57
10	37·24	11·60	·2	− ·43	−1·01
11	56·20	7·30	·3	− ·61	−1·59
12	73·69	−2·67	·9	+1·69	+ ·67

PRELIMINARY ELEMENTS

P = 478 days	γ = −14·30 km.
e = ·38	K = 15·35 km.
ω = 230°	T = J.D. 2,423,536·09

From graphical methods the foregoing preliminary elements were adopted and then a set of observation equations according to the form of Lehmann-Filhés was built up connecting the five elements γ, K, e, ω and T with the residuals for the grouped observations. In these observation equations, weighted as above, the following substitutions were made for the sake of homogeneity.

$x = \delta\gamma$	$u = -K.\delta\omega$
$y = \delta K$	$v = \cdot25495\ \delta T$
$z = K.\delta e$	

OBSERVATION EQUATIONS FOR 105 HERCULIS

1	1·000x	+ ·748y	− ·420z	− ·415w	− ·080v	−2·40 = 0
2	1·000	+ ·709	− ·961	+ ·013	+ ·139	+2·18
3	1·000	+ ·407	− ·659	+ ·470	+ ·292	+ ·30
4	1·000	+ ·018	+ ·141	+ ·676	+ ·414	+ ·17
5	1·000	− ·628	+1·106	+ ·634	+ ·628	−1·94
6	1·000	− ·889	+1·060	+ ·475	+ ·668	+ ·35
7	1·000	−1·227	− ·232	− ·105	+ ·260	+1·72
8	1·000	− ·937	− ·778	−1·010	−1·372	−2·09
9	1·000	− ·396	+ ·750	−1·277	−1·735	+1·26
10	1·000	+ ·204	+1·420	−1·183	−1·185	+ ·43
11	1·000	+ ·496	+ ·940	− ·962	− ·693	+ ·61
12	1·000	+ ·648	+ ·340	− ·740	− ·376	−1·69

These gave the following normal equations:—

6·700x	−	·018y	+	·806z	−	2·258u	−	2·078v	−	·109	= 0
		3·136	−	·795	−	·074	+	·326	−	2·488	
				3·237	−	1·229	−	1·485	−	·043	
						3·914	+	4·071	+	·229	
								4·906	−	·755	

which resulted in the following corrections to the elements:—

$$\delta\gamma = -\cdot06 \text{ km.}$$
$$\delta K = +\cdot72 \text{ km.}$$
$$\delta e = +\cdot018$$
$$\delta\omega = +4^\circ\cdot47$$
$$\delta T = +4\cdot56 \text{ days}$$

The sum of the squares of the residuals for the normal places was reduced a small amount from 16·54 to 13·53 and good agreement existed between equation and ephemeris residuals, none being greater than ·06.

The following, then, are the elements as determined for the present.

FINAL ELEMENTS

$$P = 478 \text{ days}$$
$$e = \cdot398 \pm \cdot038$$
$$\omega = 234^\circ\cdot47 \pm 5^\circ\cdot11$$
$$\gamma = -14\cdot36 \text{ km.} \pm 0\cdot41 \text{ km.}$$
$$K = 16\cdot07 \text{ km.} \pm 0\cdot57 \text{ km.}$$
$$T = \text{J.D. } 2{,}423{,}540\cdot65 \pm 4\cdot75$$
$$a \sin i = 96{,}904{,}000 \text{ km.}$$

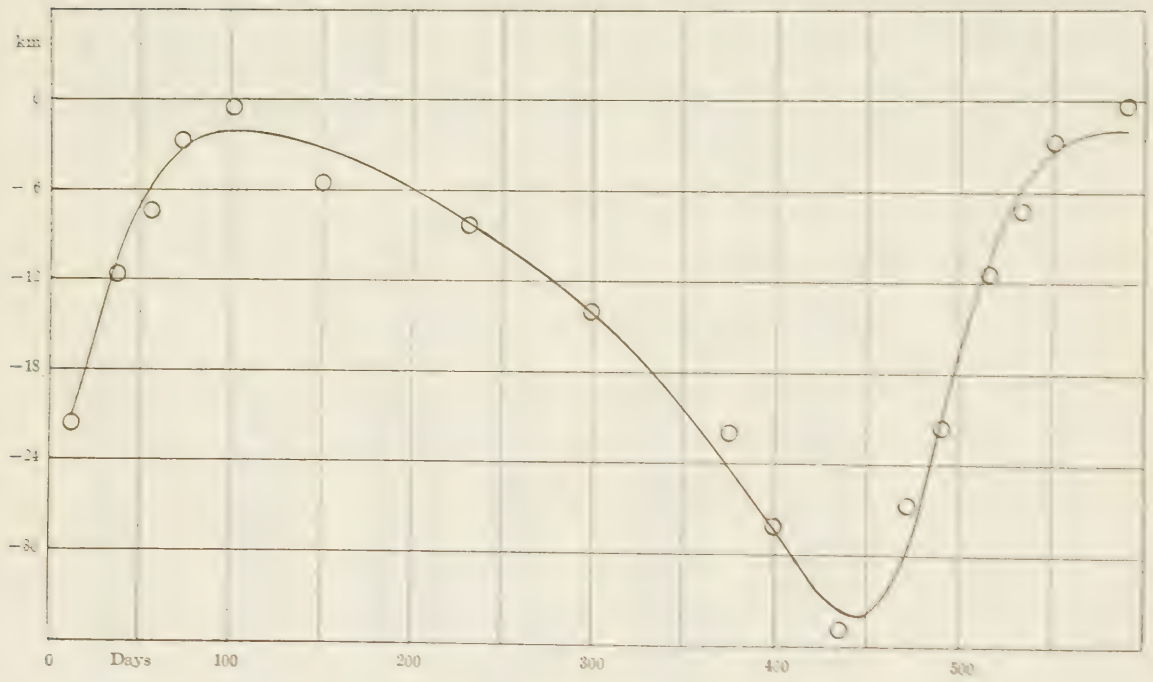

FIG. 3.—Radial Velocity Curve of 105 Herculis

In the foregoing the times are given in Greenwich Mean Time in the sense used prior to 1925.

Dominion Astrophysical Observatory,
Victoria, B.C.
April 24, 1925.

22 VULPECULAE

Abstract.—Twenty-seven spectrograms of this star whose visual magnitude is 5·4 and type G7 are made the basis of a determination of its spectroscopic orbit. The period is 251 days, the eccentricity ·042 and the probable error of a plate ±1·0 km. per sec.

Observations were begun on this star, whose right ascension is $20^h\ 11^m\cdot2$ and declination $+23°\ 12'$, in the year 1922 and twenty-seven spectrograms have been secured on which to base a determination of the orbital elements. The value obtained for the period was 251·0 days, and the observations, while not uniformly distributed over the period, are nevertheless sufficiently so to ensure a fair determination of the elements.

The spectrum is of type G7 and the plates have been measured on the spectrocomparator using α Boötis, No. 2702, as a standard plate. The table following contains the phases reckoned from the time of periastron, the velocities, the weights assigned the plates and the residual for each from the curve representing the final elements. Through a slip the weight 1 was used for the first plate, whereas it should have been 2, but any correction would be negligible.

OBSERVATIONS OF 22 VULPECULAE

Plate	Date	Julian Date	Phase	Velocity	Wt.	O–C
7852	1922 July 28	2,423,264·866	100·016	−24·1	1	+1·5
8009	Aug. 28	3,295·739	130·889	− 8·0	3	−0·4
8027	Sept. 1	3,299·802	134·952	− 2·9	3	+2·8
8052	" 7	3,305·815	140·965	− 5·8	3	−2·4
8078	" 10	3,308·766	143·916	− 2·4	2	−0·1
8136	" 16	3,314·798	149·948	− 3·6	2	−3·1
8213	Oct. 9	3,337·699	170·849	+ 4·3	3	+1·8
8255	" 27	3,355·697	190·847	+ 0·6	3	+1·8
8337	Nov. 11	3,370·571	205·721	− 6·8	3	+0·8
8379	" 14	3,373·650	208·800	−12·1	2	−2·5
8954	1923 May 7	3,547·989	132·139	− 6·7	2	+0·5
9086	June 25	3·596·908	181·058	+ 1·8	3	+0·3
9192	July 20	3,621·871	206·021	− 7·6	3	+0·3
9306	Aug. 17	3,649·798	233·948	−27·1	3	−0·7
9495	Oct. 8	3,701·667	34·817	−50·6	3	+0·4
9526	" 12	3,705·671	38·821	−49·6	2	+1·7
9539	" 22	3,715·594	48·744	−51·8	3	−1·1
10066	1924 June 2	3,939·964	22·114	−48·4	2	+0·4
10247	July 7	3,974·884	57·034	−50·7	3	−2·5
10331	" 21	3,988·844	70·994	−41·5	3	+1·0
10536	Aug. 25	4,023·758	105·908	−19·8	3	+2·1
10623	Sept. 6	4,035·753	117·903	−15·4	3	−0·8
10725	" 15	4,044·718	126·868	− 9·3	3	+0·7
10778	" 26	4,055·694	137·844	− 4·4	3	+0·1
10850	Oct. 9	4,068·723	150·873	− 1·6	3	−1·2
10910	" 31	4,090·670	172·820	+ 2·3	2	−0·2
10945	Nov. 24	2,424,114·600	196·750	− 2·1	2	+1·3

NORMAL PLACES OF 22 VULPECULAE

—	Mean Phase	Mean Velocity	Wt.	Residual O–C	
				Prel.	Final
1	100·016	−24·10	1	+1·67	+1·52
2	105·908	−19·80	3	+2·30	+2·10
3	117·903	−15·40	3	−0·48	−0·76
4	129·694	− 8·16	8	+0·38	+0·08
5	137·920	− 4·37	9	+0·37	+0·07
6	148·621	− 2·40	7	−1·63	−1·63
7	172·837	+ 3·50	5	+0·73	+0·89
8	185·952	+ 1·20	6	+0·19	+0·64
9	202·133	− 4·92	5	0·00	+0·73
10	207·135	− 9·40	5	−1·89	−1·07
11	233·948	−27·10	3	−1·47	−0·70
12	22·114	−48·40	2	+0·26	+0·43
13	36·419	−50·20	6	+0·97	+1·06
14	52·889	−51·25	5	−1·94	−1·85
15	70·994	−41·50	3	+0·98	+1·04

The observations were grouped into 15 normal places on the basis of phase. A value of the period of 251·0 days seemed most satisfactory and while there are only four cycles covered by the observations and this value may be in error by as much as a day, it was not considered that any great improvement would result by including the period in the least-squares solution. Moreover, as the eceentricity was small it was necessary to consider either T or ω fixed, and the former was the element taken as fixed.

Preliminary Elements

P	= 251·0 days	γ	= −23·52 km.
e	= ·05	K	= 27·0 km.
ω	= 120°	T	= J.D. 2,423,415·850

With these, observation equations were built up connecting the residuals with the four elements, e, ω, γ and K and for homogeneity the following substitutions were made:

x	= $\delta\gamma$	z	= K δe
y	= δ K	u	= −K.$\delta\omega$

OBSERVATION EQUATIONS OF 22 VULPECULAE

1	1·000x	− ·083y	+ ·140z	− ·955u	−1·67 = 0
2	1·000	+ ·053	− ·027	− ·954	−2·30
3	1·000	+ ·319	− ·336	− ·896	+0·48
4	1·000	+ ·555	− ·578	− ·771	−0·38
5	1·000	+ ·696	− ·701	− ·650	−0·37
6	1·000	+ ·843	− ·785	− ·454	+1·63
7	1·000	+ ·974	− ·435	+ ·090	−0·73
8	1·000	+ ·909	+ ·155	+ ·402	−0·19
9	1·000	+ ·689	+1·029	+ ·743	·00
10	1·000	+ ·593	+1·235	+ ·829	+1·89
11	1·000	− ·078	+ ·811	+1·042	+1·47
12	1·000	+ ·931	−1·186	+ ·467	−0·26
13	1·000	−1·024	− ·386	+ ·097	−0·97
14	1·000	− ·955	+ ·280	− ·323	+1·94
15	1·000	− ·702	+ ·698	− ·693	−0·98

These resulted in the following normal equations:—

$$\begin{array}{rrrrrrrrrr} 7{\cdot}100x & + & 1{\cdot}932y & - & {\cdot}540z & - & 1{\cdot}047u & + & 1{\cdot}031 & = 0 \\ & & 3{\cdot}995 & - & {\cdot}508 & - & {\cdot}178 & + & {\cdot}286 & \\ & & & & 3{\cdot}322 & + & 1{\cdot}935 & + & 1{\cdot}498 & \\ & & & & & & 2{\cdot}907 & + & 1{\cdot}541 & \end{array}$$

from which the following corrections were obtained:—

$$\begin{aligned} \delta\gamma &= -{\cdot}23 \text{ km.} \\ \delta K &= -{\cdot}01 \text{ km.} \\ \delta e &= -{\cdot}008 \\ \delta\omega &= +1^\circ{\cdot}0 \end{aligned}$$

The following, then, are the final elements obtained, with their probable errors attached.

FINAL ELEMENTS

$$\begin{aligned} P &= 251{\cdot}0 \text{ days} \\ e &= {\cdot}042 \pm {\cdot}015 \\ \omega &= 121^\circ{\cdot}0 \pm 0^\circ{\cdot}93 \\ \gamma &= -23{\cdot}75 \text{ km.} \pm 0{\cdot}24 \text{ km.} \\ K &= 26{\cdot}99 \text{ km.} \pm 0{\cdot}31 \text{ km.} \\ T &= \text{J.D. } 2{,}423{,}415{\cdot}850 \\ a \sin i &= 93{,}072{,}000 \text{ km.} \end{aligned}$$

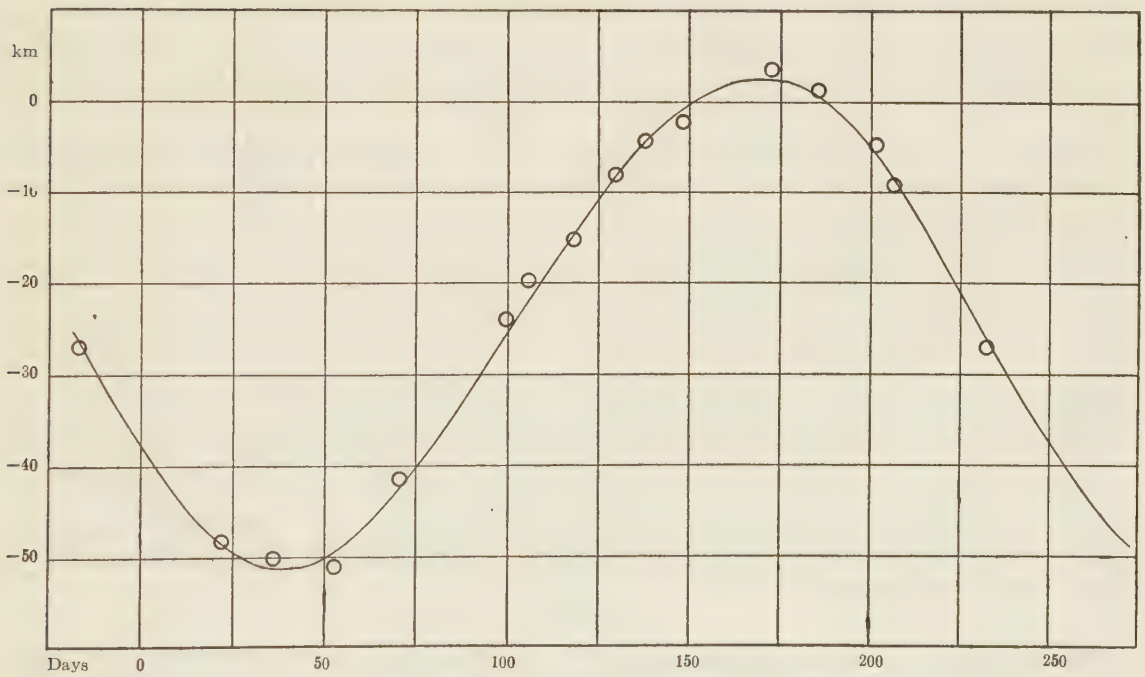

FIG. 4.—Radial Velocity Curve of 22 Vulpeculae

The curve (Fig. 4) accompanying represents the final elements, and on it are shown the observations as grouped.

Dominion Astrophysical Observatory,
Victoria, B.C.
Dec. 8, 1924.

π CEPHEI

Abstract.—Twenty-three spectrograms taken with the single-prism spectrograph and measured on the spectrocomparator against the sky as a standard, were made the basis of the determination of the elements. Five observations taken 25 years ago at the Lick Observatory were made use of also and fixed the period as 556·2 days. The semi-amplitude is 23·02 km. and the eccentricity 0·281.

The star π Cephei (1900 $\alpha = 23^h\ 04^m{\cdot}7$, $\delta = +74^\circ\ 51'$, visual magnitude 4·56 and type G5) was announced[1] as a spectroscopic binary from the Lick Observatory from five plates taken in the years 1899 and 1900. The results of four plates made at the Bonn Observatory in the years 1909 and 1912 have since been published[2] as well as two of Hnatek[3] at Vienna in 1913. For convenience of reference all are given in the table of observations.

The star is a long period visual binary listed as number 12196 in Burnham's catalogue. While the separation at present is less than a second of arc, yet the yellow component to which the present discussion relates is over two magnitudes brighter than the fainter and hence the measures should not be vitiated to any appreciable degree by the light from the fainter star.

The star has been observed here with the single-prism instrument since the beginning of 1922. The measures have been made on the comparator against the sky as a standard and in many cases against Arcturus also, the two results agreeing closely. Plate 8030, about which there was some uncertainty as to the focus of the instrument was not used in the solution, though its residual is less than that of another plate which was used.

It was felt that the Lick plates would, if used, add considerable weight to the solution, particularly as they were of three-prism dispersion. There seems to be systematic difference between ourselves and the Lick Observatory as judged from other results, and after adding $-1{\cdot}5$ km. to their values they were incorporated with our own. Such a proceeding is open to question, but a determination from our own results alone would be very little different to that here given. The observations are not distributed over the curve as uniformly as desired, and the elements, while regarded as closely approximate, are not to be treated as the best that can be secured. There is a suspicion of a small secondary oscillation, but the measures are not sufficiently numerous or refined to decide. While the probable error of a plate, $\pm 1{\cdot}58$ km. per sec., is reasonably low for single-prism dispersion, one would expect from the character of the lines for measurement a probable error not exceeding $\pm 1{\cdot}0$ km. The star will be kept on our list to secure plates occasionally.

The table of observations follows. No use was made of the Bonn and Vienna single-prism results, though the residuals from our curve are tabulated and are exceedingly small for the Bonn Observatory.

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[1] Ap. J. Vol. 14 p. 138
[2] A.N. 4750.
A.N. 197, p. 187

OBSERVATIONS OF π CEPHEI

Observatory Plate No.	Date	Julian Date	Phase	Velocity	O–C
Lick III	1899 Aug. 8	2,414,875·9	193·37	−33·0	+0·6
"	" 23	4,890·9	208·37	−36·0	−1·4
"	" 29	4,896·9	214·37	−37·0	−2·0
"	1900 Oct. 7	5,300·9	62·17	− 5·0	+1·0
"	Dec. 24	5,378·9	140·17	−23·0	+4·0
Bonn I	1909 Oct. 24	8,604·32	28·39	+ 3·1	−1·6
"	1912 Sept. 26	9,672·39	540·26	+ 8·9	−0·4
"	Oct. 9	9,685·34	553·21	+11·0	+1·2
"	Oct. 11	2,419,687·36	555·23	+ 8·8	−1·0
Vienna I	1913 Oct. 31	2,420,072·332	384·00	−20·3	+7·9
"	Nov. 21	0,093·308	404·98	−28·5	−3·5
Victoria—					
6975	1922 Jan. 6	2,423,061·594	36·07	+ 3·8	+1·4
8030	Sept. 1	3,299·869	274·34	−30·8	+4·9
8258	Oct. 27	3,355·772	330·24	−37·2	−3·3
8286	Nov. 2	3,361·672	336·14	−34·3	−0·9
8307	" 5	3,364·772	339·24	−32·5	+0·7
8311	" 8	3,367·664	342·14	−27·6	+5·4
8433	" 27	3,386·687	361·16	−28·4	+2·4
8497	1923 Jan. 13	3,433·594	408·07	−24·8	−0·1
9312	Aug. 17	3,649·969	68·24	−10·6	−2·0
9501	Oct. 8	3,701·848	120·12	−18·8	+4·2
9566	" 26	3,719·772	138·04	−25·6	+0·9
10250	1924 July 7	3,974·959	393·23	−27·7	−1·0
10334	" 21	3,988·961	407·23	−26·0	−1·3
10571	Aug. 29	4,027·895	446·17	−20·0	−3·3
10610	Sept. 3	4,032·925	451·20	−13·6	+1·9
10627	" 6	4,035·909	454·18	−12·3	+1·9
10636	" 8	4,037·876	456·15	−15·4	−1·4
10727	" 15	4,044·821	463·09	−10·8	+1·0
10853	Oct. 9	4,068·832	487·10	− 5·8	−1·3
10989	Nov. 28	4,118·723	537·00	+ 7·5	−1·3
11030	Dec. 8	4,128·716	546·99	+11·0	+1·3
11092	" 23	4,143·638	5·71	+10·7	+1·4
11197	1925 Feb. 9	2,424,191·590	53·66	− 7·3	−3·6

All the plates were considered of equal weight and some occurring at or about the same phase were grouped as shown in the table of normal places. The mean phases there listed are based on the final elements.

NORMAL PLACES FOR π CEPHEI

	Phase	Velocity	Wt.	O–C			Phase	Velocity	Wt.	O–C	
				Prel.	Final					Prel.	Final
1	36·07	+ 3·8	1	−0·3	+1·4	10	377·20	−28·0	2	+0·7	+1·1
2	57·92	− 6·9	2	−2·4	−1·9	11	407·65	−25·4	2	−1·3	−0·7
3	68·24	−10·6	1	−2·2	−2·0	12	448·67	−16·8	2	−1·2	−1·0
4	129·08	−22·2	2	+4·5	+2·8	13	455·17	−13·8	2	+0·1	+0·2
5	140·17	−24·5	1	+4·3	+2·5	14	463·09	−10·8	1	+1·0	+1·0
6	193·37	−34·5	1	+0·5	−0·9	15	487·10	− 5·8	1	−1·0	−1·3
7	211·37	−38·0	2	−2·0	−3·2	16	537·00	+ 7·5	1	−1·8	−1·3
8	333·19	−35·8	2	−2·5	−2·1	17	546·99	+11·0	1	+0·2	+1·3
9	340·69	−30·0	2	+2·7	+3·1	18	5·71	+10·7	1	−0·3	+1·4

Graphical methods in use here gave the following preliminary values of the elements.

$$\begin{aligned} P &= 556{\cdot}2 \text{ days} \\ e &= {\cdot}30 \\ \omega &= 15^\circ \\ K &= 24{\cdot}0 \text{ km.} \\ \gamma &= -19{\cdot}75 \text{ km.} \\ T &= \text{J.D. } 2{,}414{,}138{\cdot}0 \end{aligned}$$

In the observation equations which were built up the following substitutions were made.

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K \\ z &= K.\delta e \\ u &= -K.\delta\omega \\ v &= [9{\cdot}49460]\ \delta T \end{aligned}$$

OBSERVATION EQUATIONS FOR π CEPHEI

							Wt.
1	1·000x	+ ·996y	+ ·086z	+ ·786u	+1·124v	+0·3 = 0	1
2	1·000	+ ·634	− ·867	+1·017	+1·290	+2·4	2
3	1·000	+ ·472	−1·111	+1·061	+1·253	+2·2	1
4	1·000	− ·289	− ·624	+ ·893	+ ·653	+4·5	2
5	1·000	− ·378	− ·393	+ ·822	+ ·550	−4·3	1
6	1·000	− ·635	+ ·520	+ ·458	+ ·220	−0·5	1
7	1·000	− ·677	+ ·725	+ ·332	+ ·139	−2·0	2
8	1·000	− ·566	+ ·697	− ·438	− ·262	+2·5	2
9	1·000	− ·540	+ ·625	− ·480	− ·286	+2·7	2
10	1·000	− ·374	+ ·175	− ·670	− ·420	−0·7	2
11	1·000	− ·180	− ·307	− ·805	− ·558	+1·3	2
12	1·000	+ ·175	− ·952	− ·915	− ·786	+1·2	2
13	1·000	+ ·245	−1·031	− ·921	− ·825	−0·1	2
14	1·000	+ ·332	−1·107	− ·921	− ·873	−1·0	1
15	1·000	+ ·624	−1·125	− ·865	− ·988	+1·0	1
16	1·000	+1·212	+ ·385	− ·308	− ·591	+1·8	1
17	1·000	+1·272	+ ·760	− ·111	− ·305	−0·2	1
18	1·000	+1·282	+1·010	− ·207	+ ·218	+0·3	1

There resulted the following normal equations:—

$$\begin{array}{rrrrrrrrrrr} 27{\cdot}000x & + & 2{\cdot}033y & - & 4{\cdot}093z & - & 2{\cdot}845u & - & 1{\cdot}502v & + & 2{\cdot}400 = 0 \\ & & 10{\cdot}629 & - & 3{\cdot}002 & + & {\cdot}945 & + & 1{\cdot}145 & + & 9{\cdot}334 \\ & & & & 15{\cdot}176 & + & 1{\cdot}097 & + & {\cdot}262 & + & 1{\cdot}180 \\ & & & & & & 14{\cdot}669 & + & 13{\cdot}491 & - & 6{\cdot}200 \\ & & & & & & & & 13{\cdot}505 & - & 1{\cdot}913 \end{array}$$

from which the following corrections resulted:

$$\begin{aligned} \delta\gamma &= + {\cdot}12 \text{ km.} \\ \delta K &= - {\cdot}98 \text{ km.} \\ \delta e &= - {\cdot}019 \\ \delta\omega &= -9^\circ{\cdot}30 \\ \delta T &= -11{\cdot}67 \text{ days} \end{aligned}$$

so that the final elements, with their probable errors attached are as follows:—

FINAL ELEMENTS

$$
\begin{aligned}
P &= 556{\cdot}2 \text{ days} \\
e &= {\cdot}281 \pm {\cdot}020 \\
\omega &= 5^\circ{\cdot}70 \pm 4^\circ{\cdot}21 \\
K &= 23{\cdot}02 \text{ km.} \pm 0{\cdot}59 \text{ km.} \\
\gamma &= -19{\cdot}63 \text{ km.} \pm 0{\cdot}37 \text{ km.} \\
T &= \text{J.D. } 2{,}414{,}126{\cdot}33 \pm 5{\cdot}83 \text{ days} \\
a \sin i &= 168{,}970{,}000 \text{ km.}
\end{aligned}
$$

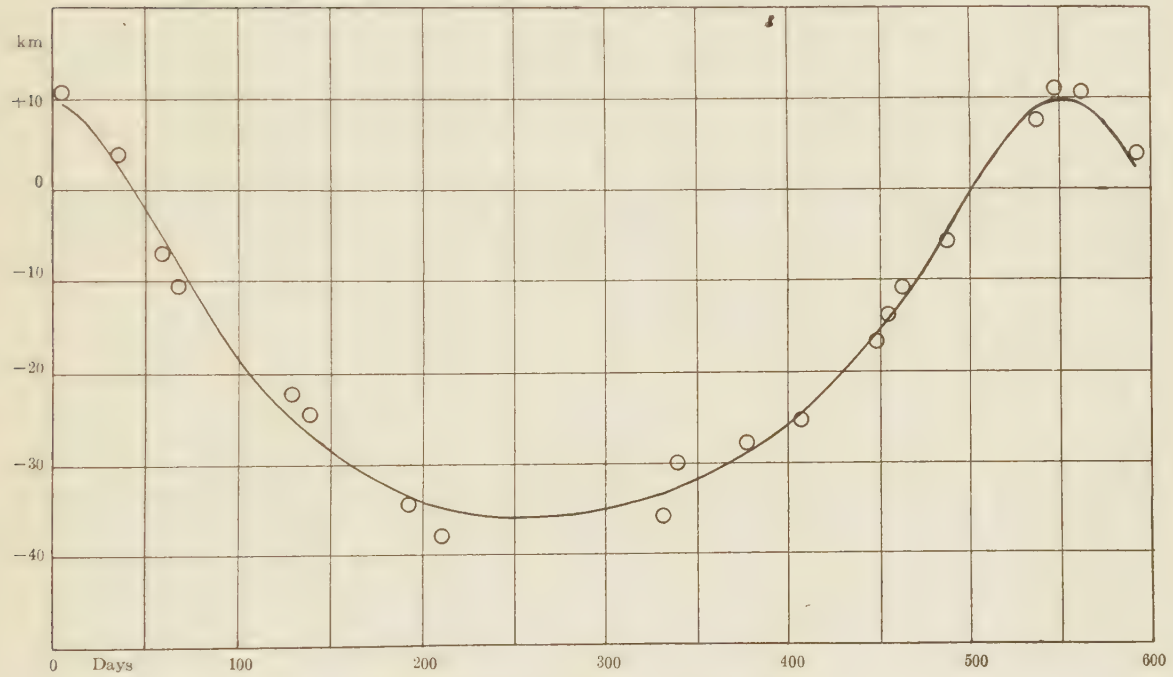

FIG. 5.—Radial Velocity Curve of π Cephei

The curve shown (Fig. 5) represents the final elements.

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THE VELOCITY CURVES OF 12 LACERTAE AND THE RADIAL VELOCITIES OF 48 STARS

BY WILLIAM H. CHRISTIE

ABSTRACT

Spectra. One hundred and fifty-two spectra of the short-period, variable velocity star 12 Lacertae, (α 22h 37·0m, δ +39° 43′) have been measured. These include two series taken by Dr. R. K. Young in 1922 and 1923 and three by the writer in 1924.

Amplitude. The last of the series consisting of 76 spectra taken in succession and covering two complete cycles, indicates that the change in amplitude, previously noted by Young, is rapid.

H and K Lines of Calcium. The velocity derived from the calcium lines is in close agreement with the solar motion, being −14·1 km./sec. whereas the solar component is −11·0 km./sec.

Radial Velocities of H.R. Stars. In addition the radial velocities of 48 stars, selected from a general programme of H.R. stars, have been determined, in the majority of cases 4 or more spectra of each star being obtained. Of these, 9 stars were found to be binaries.

INTRODUCTION

During the summer months of 1923 and 1924 the writer was employed as assistant at this Observatory to take part of the observing during temporary absences of the regular members of the staff. During the summer of 1923 a card catalogue of the radial velocities of the stars was brought up to date and the radial velocities of 14 stars from a programme of H.R. stars were measured and the results published in the Journal of the Royal Astronomical Society of Canada for April, 1924.

For 1924, 34 additional stars from the H.R. programme, of which spectrograms had been obtained by other members of the staff, were selected for measurement and the results of the measures of these stars with the 14 mentioned above are given below.

As a further useful investigation, Dr. Reynold K. Young suggested a continuation of the observation and measurement of the short-period variable-velocity star, 12 Lacertae, of which he himself had already obtained and measured several complete cycles. This

investigation then, was undertaken by the writer, additional series being obtained on July 28, July 31 and Sept. 9, 1924. These three series with two unmeasured sets previously obtained by Dr. Young and kindly turned over by him to the writer, were measured and reduced and the results are given below.

It has seemed preferable to discuss the measures of 12 Lacertae before giving the radial velocities of the H.R. stars.

The Velocity Curves of 12 Lacertae

The curious changes in the amplitude and the systematic velocity of this star disclosed in the earlier measures and extended and amplified by these later measures, make it almost essential for complete treatment to give a short summary of the previous results by Dr. Young*.

The star has a variable velocity of short period which can not in general be represented by elliptic motion, and the velocity curves undergo curious changes in amplitude and form, quite analogous to the behaviour of the similar short-period stars β Cephei, σ Scorpii and β Canis Majoris. The results of Young's investigations cannot be better summarized than in his own words:—

1. "From the measures of spectra of 12 Lacertae taken in 1918 it is definitely shown that the amplitude of the radial velocity curve varies from night to night, being as small as fifteen or twenty kilometers at some times and as large as seventy at others."

2. "The shape of the curve is not constant but a simple period will harmonize fairly satisfactorily the observations taken between 1908 and 1918 and serves to predict the approximate times of maximum and minimum velocities."

3. "The spectral lines undergo a periodic variation in width, the lines being wide and diffuse at periastron passage and sharper and narrower at apastron. When the amplitude exhibited by the curve is small the lines are generally more diffuse than when the range is large."

4. "The velocity of the centre of gravity as determined from plates taken in any one year is constant but plates taken in 1913, 1914, 1915 and 1918 show that it is subject to a long-period variation."

5. "The amplitude exhibited by the calcium lines is smaller than for the other spectral lines and they are always sharp and narrow even when the others have become wide and diffuse. When the range in the hydrogen and helium lines is high then the amplitude exhibited by the calcium lines is easily discernible, when the hydrogen and helium lines show a small range, the amplitude exhibited by the calcium is masked more or less completely by the error of determination."

These curious results rendered the star worthy of further investigation and for that purpose there were available two series of spectra covering complete cycles, which were obtained by Dr. Young on Nov. 22, 1922 and Sept. 17, 1923, and very kindly handed over by him to the writer for measurement. Three more series were obtained during the summer of 1924 on July 25, July 31 and September 9. The last of these extended

*These Publications, I, p. 105.

over two complete cycles of the star and is especially interesting because of the portrayal of the rapid change in amplitude, as all the earlier series had covered only one cycle.

The star is bright, magnitude about 5·2, and under average conditions with single-prism dispersion, 29A to the millimetre at Hγ, a good spectrum can be obtained in five minutes. In these series, however, in order to increase the accuracy of measurement and the resulting radial velocity, the slit was made narrower and the spectrum wider than usual, hence increasing the exposure time about 50 per cent. The greatest care was taken in the guiding to keep the star image accurately centered on the slit in order to avoid, as far as possible, the possibility of systematic displacement of the lines and the resultant error of the radial velocity. On the night of September 9, when the two cycles were covered, 76 spectra were obtained and, to minimize time spent in changing and developing plates, four spectra were made, side by side, on each plate.

The 152 spectra of 12 Lacertae were measured on the Toepfer micrometer microscope of the Observatory, using the methods and reduction tables described in Vol. II, No. 1, Publications of this Observatory.

The lines measured in this star are given in the following table (Table I), the wave lengths employed, which are in many cases adjusted values, being the same as those used by Young in order to make these results directly comparable with his.

TABLE I

ADOPTED WAVELENGTH OF LINES USED IN MEASURING RADIAL VELOCITY OF 12 LACERTAE

λ	Element	λ	Element	λ	Element
3933·825	Ca+	4119·409	O	4349·693	O
3964·875	He	4128·211	Si	4351·526	O
3968·625	Ca+	4131·047	Si	4367·010	O
3970·242	H	4144·000	He	4388·130	He
3995·260	N	4153·600	O	4415·050	O
4009·495	He	4190·080	O	4417·120	O
4026·349	He	4253·983	S	4471·648	He
4069·409	O	4267·384	C+	4481·400	Mg+
4072·125	O	4317·270	O	4552·762	Si III
4076·090	O	4319·287	O	4567·966	Si III
4101·890	H	4340·634	H	4574·918	Si III

The measures of the last series when plotted showed several outstanding deviations from uniform curves and it was considered advisable to have some of the plates independently remeasured. This was kindly undertaken by Mr. S. N. Hill, astronomical computer at the Observatory, with the result of smoothing out many of the discrepancies. The differences between the measures by the writer and Mr. Hill were, in general, not greater than would be expected from the character of the lines, and the final value used is the mean of the two measures. The spectra thus remeasured are indicated by an asterisk in the following table and by the half-filled circles in the accompanying velocity curve (Fig. 5). No velocity is given for the calcium lines in the series of July 31, 1924, as the plates taken on this night are not strong enough for reliable settings to be made on these lines.

TABLE II

INDIVIDUAL MEASURES OF 12 LACERTAE

Date	Phase	Velocity		Date	Phase	Velocity	
		General	Vo (Ca)			General	Vo (Ca)
1922, Nov. 22·556	·006	− 6·7	− 9·0	1924, July 28·922	·141	−38·8	−21·0
·569	·019	+ 1·1	−16·0	·928	·148	−36·0	−26·5
·583	·033	+ 8·9	− 5·3	·936	·156	−31·2	−17·4
·597	·047	+13·9	− 6·2	·946	·166	−27·7	− 5·8
·611	·061	+ 8·4		·951	·171	−24·8	−13·8
·625	·075	+ 1·9	−21·3	·959	·179	−13·1	−16·6
·639	·089	− 3·5	− 4·5	1924, July 31·791	·090	−29·0	
·653	·103	−21·2	− 3·5	·799	·098	−27·8	
·667	·117	−35·9	−23·8	·807	·106	−30·5	
·681	·131	−33·0		·816	·115	−43·0	
·695	·145	−31·1		·826	·125	−39·1	
·708	·158	−28·5	−26·2	·835	·134	−38·2	
·722	·172	−24·0	−16·3	·844	·143	−42·0	
·736	·186	− 7·4	−20·8	·854	·153	−34·5	
1923, Sept.14·679	.....	−26·0	−15·6	·864	·163	−35·9	
·695	.....	−44·6	−19·4	·873	·172	−18·8	
·707	.....	−40·4	− 8·9	·883	·000	−10·3	
1923, Sept. 17·640	·166	−31·7		·893	·010	− 4·1	
·653	·179	−17·1		·903	·020	+ 5·3	
·668	·001	−10·9	−18·7	·914	·031	+13·5	
·681	·014	− 8·5	−15·6	·925	·042	+36·1	
·694	·028	− 1·4	−17·3	·934	·051	+24·7	
·707	·040	+ 0·3	−13·0	·944	·061	+ 4·7	
·725	·056	+ 1·1	− 6·7	·954	·071	+ 8·8	
·739	·074	− 3·2	− 5·6	1924, Sept. 9·637*	·001	−14·5	−11·2
·753	·086	− 5·2	− 9·2	·641*	·005	−16·0	−10·2
·770	·103	−15·6	−21·4	·645*	·009	−14·0	−12·6
·786	·119	−24·7	−14·8	·649	·013	− 9·5	−21·7
·800	·133	−30·0	−24·0	·654	·018	− 9·2	−12·9
·816	·149	−31·0	−13·8	·660*	·024	− 5·2	−14·6
·827	·160	−29·0	−18·2	·667*	·031	− 4·0	− 7·1
·839	·172	−23·8	−16·0	·672*	·036	− 5·0	−10·1
1924, July 28·796	·016	− 2·0	−12·3	·677	·041	− 1·0	−12·9
·801	·021	− 2·4	+ 2·2	·686*	·050	− 1·0	−12·1
·808	·028	+ 8·4	−10·7	·697	·061	− 3·4	−17·5
·817	·037	+ 6·6	−13·8	·704	·068	− 7·0	−20·5
·822	·042	+ 6·5	−14·6	·709*	·073	−11·7	−10·2
·831	·051	+ 8·6	− 2·8	·714	·078	−13·9	−10·1
·837	·057	− 0·2	−10·3	·720*	·084	−17·5	−10·5
·844	·064	0·0		·726*	·090	−17·1	− 5·9
·850	·070	− 6·6	−12·9	·731	·095	−19·6	− 9·3
·855	·075	− 9·0	− 2·9	·736	·100	−23·2	−17·7
·861	·081	5·0	−14·7	·742	·106	−20·6	−24·3
·887	·087	−12·2	− 2·6	·747	·111	−26·4	−25·2
·873	·093	−14·2	−12·5	·752	·116	−26·9	−15·6
·878	·098	−10·7	−15·2	·756	·120	−28·7	−16·1
·885	·105	−12·6	− 7·7	·761	·125	−32·0	−21·4
·892	·112	−19·6	−12·0	·766	·130	−31·2	−31·7
·899	·119	−27·2	−17·0	·771*	·135	−34·8	−16·3
·905	·125	−34·0	−12·4	·775*	·139	−27·5	−19·7
·910	·131	−38·9	−13·2	·779*	·143	−25·8	−18·9
·916	·136	−36·3	−12·6	·783*	·147	−23·4	−15·1

TABLE II—Concluded

INDIVIDUAL MEASURES OF 12 LACERTAE—Concluded

Date	Phase	Velocity		Date	Phase	Velocity	
		General	Vo (Ca)			General	Vo (Ca)
1924, Sept. 9·788*	·152	−27·7	−19·2	1924, Sept. 9·898*	·069	−15·2	− 7·6
·792	·156	−24·9	−10·4	·902*	·073	−16·1	−12·3
·796	·160	−24·7	−16·1	·906*	·077	−12·7	− 7·5
·800	·164	−25·4	−14·9	·911*	·082	−20·2	−14·4
·804	·168	−18·6	−23·0	·918	·089	−23·1	−15·8
·809*	·173	−22·2	−21·0	·923	·094	−21·2	− 9·9
·812	·176	−15·7	−17·1	·929	·100	−24·3	−11·4
·818*	·182	−13·9	−10·4	·936	·107	−24·0	− 5·5
·821	·185	−15·7	− 9·8	·943	·114	−21·3	− 8·4
·827	·191	−10·2	−16·4	·948	·119	−24·2	−15·0
·832	·003	−13·6	−12·0	·952	·123	−22·1	− 3·2
·838	·009	−12·2	−11·3	·956	·127	−19·1	− 9·2
·842*	·013	−10·9	−11·7	·961	·132	−20·8	−10·0
·846*	·017	− 7·0	− 2·0	·969	·140	−22·4	−15·9
·850*	·021	− 5·8	− 9·1	·975	·145	−18·6	−16·6
·855	·026	− 5·5	− 6·5	·980	·151	−20·6	
·861	·032	− 7·0	−11·2	·984*	·155	−18·4	− 8·0
·867	·038	− 3·4	−11·5	·990*	·161	−20·3	− 6·8
·873	·044	− 3·0	−14·2	·994*	·165	−20·8	− 9·6
·878	·049	− 6·3	−17·2	·999*	·170	−23·2	−13·7
·881	·052	− 5·0	−14·7	1924, Sept. 10·006*	·177	−20·7	− 2·6
·885*	·056	−10·7	− 6·6	·011*	·182	−16·3	−16·5
·890*	·061	−12·0	− 9·5	·017*	·188	−15·8	− 8·0
·894*	·065	−11·5	−15·0	·024*	·001	−20·0	− 5·0

In the foregoing table of measures (Table II) the columns contain successively the plate number, the date (G.M.T.), the phase computed from the initial phase and period finally accepted and the velocity from the stellar lines, H and K of calcium.

These measures are plotted in the accompanying graphs, Figs. 1 to 5, in which the peculiar changes in the amplitude and form of the velocity curves are strikingly indicated and which may be briefly discussed with advantage.

The changes in amplitude which were previously noted by Dr. Young are even more strikingly demonstrated by the later plates. A glance at Table IV, in which the approximate values of K for the different series in 1922, 1923 and 1924 are given will show the range in amplitude disclosed by these series. It remained, however, for the observations of September 9–10, 1924, Fig. 5, to show the suddenness of this change of amplitude. The number and good quality of these plates, with the remeasurement of many of them by Mr. Hill, make this determination of the form and amplitude of the curve especially trustworthy. While the earlier series had indicated the certainty of a change in amplitude, they had given no evidence that this change was a sudden one, and indeed the physical probability of such a change seems small, nevertheless the spectra of September 9–10 show that the early cycle with an amplitude of 30 kms. is immediately followed by one

with very little, if any, change in velocity. Of the reality of this sudden change in amplitude there can be no reasonable doubt as may be seen from the run of the velocities in Fig. 5, but no attempt is made at an explanation of this phenomenon.

Dr. Young has stated that all the previous observations agreed with a period of 0·1930890 days and that those of 1918 also fitted into the same period. From some of the 1923 and 1924 velocity curves it appeared as if a shorter period would be more suitable, and a period of 0·18235 days was found which fitted the 1923 and 1924 observations, but when carried back to 1922 and earlier it would not suit, whereas the period of 0·1930890 days suited all the observations within the limits of the accuracy with which the phase was determined. The following table (Table III), shows the approximate positions of zero phase, determined graphically from the curves, taken as the time when the velocity curve, with the velocities becoming more positive, crosses the γ line.

TABLE III

	J.D. of Zero Phase	Differences	Residuals of Periods		Adjusted Phases	Residual O–C
			0·18235	·01930890		
1	2,420,761·149				2,420,761·153	−·004
		1071·851	−·002	+·014		
2	1,833·000				1,832·990	+·010
		384·848	+·001	−·013		
3	2,216·848				2,216·851	−·003
		409·928	+·005	·000		
4	2,626·776				2,626·779	−·003
		283·071	+·064	+·003		
5	2,909·847				2,909·847	·000
		471·703	−·036	−·013		
6	3,381·550				3,381·564	−·014
		299·117	+·063	+·022		
7	3,680·667				3,680·659	+·008
		315·113	+·012	−·008		
8	3,995·780				3,995·780	·000
		3·103	+·004	+·014		
9	3,998·883				3,998·869	+·014
		39·753	+·001	−·023		
10	2,424,038·636				2,424,038·646	−·010
	Difference 10−1	3277·487	−·072	−·006		

The times of 1 and 2 in the above table were obtained from Young's paper* with the correction of a misprint in 2. Nos. 3, 4 and 5 were obtained from the velocities of the years 1919, 1920 and 1921 which Dr. Young was kind enough to send the writer in advance of publication. The remaining values are from the present measures. The difference between the successive values of the times of zero phase are given in the third column, the last being the whole interval covered.

*These Publications I, p. 105.

It is obvious that if the period is constant that all these differences must be integral multiples of it, and further, if this condition is fulfilled within the errors of determination of the phases, the probability of its correctness where so many different intervals are involved is very great. Further, the two short intervals between 8, 9 and 10 limit closely the possible periods, and, with the approximate value obtained from the single velocity curves, confine it to two periods—Young's of 0·1930890 days and the shorter one of 0·18235 days. The shorter of these two periods seems to fit the accompanying velocity curves even better than the longer, but owing to latitude in drawing, the decisive test must be the agreement with the whole series.

Columns 4 and 5 contain the residuals between the observed differences of column 3 and the nearest integral multiple of the two periods, and it is evident that Young's period is the correct one for there are two residuals of a third of the period for the shorter one. It is, however, remarkable that the shorter period fits six of the intervals more closely than the longer one, but if this is more than a coincidence the physical meaning is not obvious. The longer period, especially when the phases are adjusted slightly as given in the sixth column, make the residuals in no case greater than 0·014 days from the graphically determined phases, certainly well within the errors of determination. There seems no reasonable doubt, then, that the period of 0·1930890 days is the correct one so far as the observations up to the present can determine, while it also appears to be constant over the interval observed.

The final table (Table IV) gives the dates and the Julian dates of the zero phases with the amplitudes. The systematic velocity γ has been carefully determined by the method of equal areas from the velocity curves by the planimeter. The last column gives the velocity from the calcium lines.

TABLE IV

DATA OF OBSERVED CYCLES

Date	Julian Day	K	γ	Vo (Ca)
1922 Nov. 22	2,423,381·550	22·5	−11 km.	−14·8
1923 Sept. 17	3,680·667	16·0	−13 "	−14·7
1924 July 28	3,995·780	22·5	−14 "	−11·9
1924 July 31	3,998·883	36·0	−14 "	
1924 Sept. 9	4,038·636	15·0 5·0	−16 "	−12·7

The changes in systematic velocity will be discussed later by Dr. Young and there remains only to mention the behaviour of the H and K lines of calcium. The values obtained here along with the corrected values recently given by Dr. Young*, show that in all probability the calcium cloud causing these absorption lines is practically stationary in space. The velocity derived from these lines differs by −2 1 km./sec. from the reflex of the solar motion of −11·0 km./sec.

* Jour. R.A.S.C., *19*, p. 46.

Before concluding this discussion the writer cannot omit referring to the work of Guthnick† upon the variation of the light of this star. This variation was discovered by Stebbins and announced by him in Popular Astronomy, Vol. 25, p. 657. Guthnick has found by the use of the photo-electric cell that the light curve of 12 Lacertae is very similar to the radial velocity curve. The period of the light curve adopted by him is Young's period of ·1930890 days and the change in amplitude, which is well shown by his observations, is relatively very great. The amplitude of this curve varies from a curve which is masked by the errors of observation, which are surprisingly small, to a well defined curve with an amplitude of over 0·2 magnitudes.

As a further investigation of this star the writer hopes to obtain additional plates of 12 Lacertae this year with especial reference to the problems of the period, amplitude and systematic stellar and calcium velocities. It is proposed to obtain spectra at the predicted maxima and minima on several successive nights which should disclose the period of the variation of the amplitude, if such a period exists.

The Radial Velocities of 48 Stars

Of the H.R. stars selected from the radial velocity programme for measurement by the writer, many had either too few plates obtained to give a reliable velocity or else the spectra were of too poor a quality to give satisfactory results with the number obtained. In order to offset this the writer obtained additional plates during the summer months of 1923, 1924 and 1925 to complete the following list. In the case of some of the stars in the early hours of Right Ascension, however, it has not been possible to obtain the necessary spectra. These measures are included in the following table with the algebraic mean but with no probable error appended because of the little meaning attached to this function when so few observations are available. Those plates that were obtained in 1925 are given with the old G.M.T. date to conform to the rest of the table.

The radial velocities of 14 of these stars have already been published, but in several cases additional plates have been obtained which have, in one or two cases, slightly altered the previously published velocity.

The table itself is self-explanatory, except, perhaps, the sixth column where the regions measured are given if the plate has been measured on the Hartmann spectro-comparator. Here the symbol = denotes that the alternate regions between and including the limiting numbers have been measured and reduced as described in these Publications, Vol. II, No. 1.

In conclusion the writer wishes to express his indebtedness to the director and the staff for their valuable help and constructive criticism.

Dominion Astrophysical Observatory,
Victoria, B.C.
May 1925.

† A.N. 4983 and Jubilaumsnummer, p. 11.

INDIVIDUAL MEASURES OF 48 STARS

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
				km./sec.		
H.D. 6966	K5	8128	1922 Sept. 15·931	−15·3*	13=23	While the first plate is
01h 05·0m	6·36	8454	Nov. 20·711	+ 0·8	15=23	discordant, there is no
+15° 09′		8504	1923 Jan. 22·597	− 0·1	17=23	reason to believe that
		10589	1924 Aug. 31·952	+ 1·7	11=23	it should be rejected.
		10603	Sept. 2·980	− 4·6	13=23	The star is probably a
		10691	Sept. 11·878	− 0·4	11=23	binary of small range.
				− 3·0		
H.D. 7853	A3	8146	1922 Sept. 17·886	− 0·5	14	Binary of small range.
01h 13·1m	6·34	8246	Oct. 19·816	+ 2·5	15	The lines are sharp.
+36° 52′		8487	Dec. 28·648	+12·3*	15	
		9298	1923 Aug. 14·991	+ 7·5	15	
		10497	1924 Aug. 11·989	− 2·1*	0=23	
		10547	Aug. 26·962	+ 4·1	7=23	
H.D. 11031N	A2	8147	1922 Sept. 17·940	+ 1·5	9	
01h 43·3m	5·99	8247	Oct. 19·845	− 5·3	9	
+47° 24′		8445	Nov. 28·665	− 5·0	9	
		9297	1923 Aug. 14·958	− 4·3	15	
				−3·4 ±1·1		
H.D. 11031S	A2	8170	1922 Sept. 23·897	−11·7	4	Binary. This star forms,
01h 43·3m	5·99	8248	Oct. 19·887	−23·4	4	with H.D. 11031N, the
+47° 24′		8446	Nov. 28·758	+ 2·5	6	visual double Σ162=
		9296	1923 Aug. 14·884	−42·5	10	B.G.C. 941. Red com-
				+60·0		ponent 2 lines only.
		9319	Aug. 18·941	− 1·9	6	
H.D. 13594	Fo	6486	1921 Aug. 25·994	− 7·9	22	
02h 07·6m	6·03	8045	1922 Sept. 5·939	− 8·1	19	
+47° 02′		8129	Sept. 15·973	− 9·2	20	
		8395	Nov. 21·724	− 5·7	13	
				−7·7 ±0·5		
H.D. 16247	Ko	8455	1922 Nov. 30·767	−29·1	1=23	
02h 31·3m	6·04	8531	1923 Jan. 27·689	−21·0	11=23	
+07° 18′		9657	Dec. 28·700	−25·1	8	Short focus camera.
				−25·1		
H.D. 19735	Ko	8046	1922 Sept. 5·977	−32·3*	13=23	
03h 05·5m	6·42				8	
+47° 22′		8148	Sept. 17·991	−32·1*	16=23	
					8	
		8262	Oct. 28·861	−41·3	8	
		8396	Nov. 21·783	−40·6*	17=23	
					8	
				−36·6		
H.D. 53686	Ko	7383	1922 Mar. 28·684	+17·0	11=23	Binary.
07h 00·9m	6·13	7435	April 11·660	− 6·9*	15=23	
+34° 09′		7448	Dec. 31·936	+20·5	17=23	
		11614	1925 May 13·700	+22·9	17=23	

*Mean of two measures.

INDIVIDUAL MEASURES OF 48 STARS—Continued

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
				km./sec.		
H.D. 80546	Ko	7387	1922 Mar. 31·734	+27·5	11=23	
09h 15·4m	6·22	7471	April 18·681	+27·1	13=23	
+33° 21′		8533	1923 Jan. 27·905	+26·9	17=23	
				+27·2		
H.D. 83787	K5	7339	1922 Mar. 24·738	−10·7	13=23	
09h 35·7m	6·08	7384	May 28·730	− 7·1	15=23	
+31° 43′		8656	1923 Mar. 14·804	−12·0	13=23	
		8676	Mar. 17·777	−23·1	17=23	
				−13·2		
H.D. 96834	Ma	7140	1922 Feb. 18·866	+21·9	13=23	
11h 04·0m	6·03	7235	Feb. 26·846	+17·8	13=23	
+43° 45′		7331	Mar. 22·756	+16·9	17=23	
		7533	May 5·704	+12·8	15=23	
		11616	1925 May 13·819	+18·0	17=23	
				+17·5 ±1·0		
H.D. 97334	Go	7340	1922 Mar. 24·778	− 2·1	11=23	
11h 07·1m	6·32	7406	April 4·783	− 1·6	7=23	
+36° 21′		7472	April 18·751	− 4·0	7=23	
		8625	1923 Feb. 27·918	+ 5·3	15=23	Very poor plate. Omitted
		11636	1925 May 16·796	− 6·7	11=23	in mean.
				−3·6 ±0·8		
H.D. 100470	Ko	8657	1923 Mar. 14·855	+16·8	1=23	Probably binary of small
11h 28·6m	6·33	8771	April 1·788	+23·0	9=23	range.
+37° 23′		8839	April 21·791	+22·1	13=23	
		8878	April 24·758	+ 7·9	11=23	
		8904	May 4·704	+ 7·4*	13=23	
				+15·4		
H.D. 101013	Ko	9846	1924 April 16·785	− 6·5	15=23	
11h 32·4m	5·99	9904	May 6·707	− 2·8	17=23	
+51° 10′		9969	May 16·706	− 4·8*	11=23	
				− 4·5		
H.D. 106884	K2	7074	1922 Jan. 27·950	−43·6	11=23	
12h 12·5m	6·00	7236	Feb. 26·894	−37·4	7=23	
+53° 45′		7303	Mar. 18·848	−42·9	13=23	
		7332	Mar. 22·833	−42·9	11=23	
		8973	1923 May 20·722	−41·9	7=23	
				−41·9 ±0·6		
H.D. 112264	Mb	7407	1922 April 4·824	−18·3	11=23	
12h 50·4m	6·02	7473	April 18·790	−21·1	13=23	
+47° 45′		7589	May 15·717	−14 8	9=23	
		8658	1923 Mar. 14·899	−17·7	7=23	
		11617	1925 May 13·889	−16·5	13=23	
				−17·7 ±0·7		

INDIVIDUAL MEASURES OF 48 STARS—Continued

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
H.D. 114326	Ko	7534	1922 May 5·779	−17·0	11=23	
13h 04·8m	6·18	7611	May 26·721	−12·3	15=23	
+17° 22′		8659	1923 Mar. 14·944	−21·9	11=23	
				−17·1		
H.D. 114780	K5	7625	1922 May 29·735	+25·0	15=23	
13h 07·6m	5·82	8738	1923 Mar. 27·870	+23·8	17=23	Half weight.
+12° 05′		8756	Mar. 29·852	+21·1	17=23	Half weight.
		8772	April 1·834	+25·0	15=23	
				+24·1 ±0·5		
H.D. 116581	Ma	6029	1921 May 12·892	− 0·1	15=23	
13h 19·4m	6·37	6090	May 27·711	+ 1·0	20−23	Very poor plate.
+32° 33′		6923	Dec. 25·079	+ 1·3	13=23	
		7333	1922 May 22·918	− 0·7	13=23	
		8958	1923 May 12·753	− 1·7	15=23	
				−0·2 ±0·4		
H.D. 118839	Ko	6135	1921 June 2·715	−12·2	17=23	
13h 34·3m	6·46	7237	1922 Feb. 26·941	−12·7	11=23	
+18° 47′		7408	April 4·873	−11·3	15=23	
		7474	April 18·843	−10·3	15=23	
				−11·6 ±0·4		
H.D. 121560	F5	6026	1921 May 12·792	−16·6	7=23	
13h 51·1m	6·15	6112	May 30·716	−15·3	9=23	
+14° 34′		7389	1922 May 31·866	−10·6	9=23	
		8974	1923 May 20·772	−13·4	7=23	
				−14·0 ±1·0		
H.D. 121682	F2	7638	1922 June 8·724	−24·0	1=23	
13h 51·8m	6·29	8787	1923 April 4·904	−24·2	1=23	
+32° 31′		8858	April 22·881	−25·0	1=23	
		8890	April 25·844	−20·5	1=23	
				−23·4 ±0·7		
H.D. 125180	Ma	7535	1922 May 5·854	−19·7	15=23	Poor, omitted in mean.
14h 12·7m	6·05	7590	May 15·804	−13·4	11=23	
+15° 44′		8660	1923 Mar. 14·984	−13·5	15=23	Poor.
		8758	Mar. 29·938	−11·6	13=23	
		8773	April 1·885	−10·2	17=23	
				−12·2 ±0·6		
H.D. 125658	A2	8627	1923 Feb. 23·024	+ 0·6	17=23	Interagreement of individual settings is poor in this star.
14h 15·8m	6·34	8842	April 21·909	− 1·1	11=23	
+30° 53′		8907	May 4·841	− 1·7	7=23	
		9783	1924 Mar. 21·933	+ 3·6	7=23	
				+0·3 ±0·8		
H.D. 127304	B9	8981	1923 May 23·794	−22·3	12	Binary.
14h 25·5m	5·96	9089	June 26·729	−13·3	12	
+32° 14′		9997	1924 May 21·732	−16·3	11	
		10010	May 24·793	− 6·7*	9	
		10210	July 3·709	− 8·7	13	
		11618	1925 May 13·961	+ 0·3	10	
		11622	May 14·774	− 4·9	7	Short focus camera. Half weight.

INDIVIDUAL MEASURES OF 48 STARS—Continued

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
H.D. 128093	F2	8873	1923 April 23·931	−13·7	26	
14h 29·9m	6·28	8947	May 7·793	− 6·7	13	
+32° 59′		8968	May 19·841	−10·4	17	
		10211	1924 July 3·730	−14·1	7=23	
				−11·2 ±1·2		
H.D. 129132	F5	9005	1923 June 3·836	−18·7	7=23	Binary.
14h 35·8m	6·17	9072	June 18·794	−34·6	7=23	
+22° 34′		9287	Aug. 14·686	+ 4·4	19	
		9322	Aug. 20·710	+15·2	12	
H.D. 130603	F5	7626	1922 May 29·820	−28·8	1=23	Variation in velocity may
14h 44·0m	6·05	7665	June 13·758	−37·4	7=23	be real.
+24° 47′		8881	1923 April 24·848	−29·3	1=23	
		8908	May 4·878	−31·6	1=23	
		8961	May 12·829	−32·3	1=23	
		9998	1924 May 21·773	−28·6	1=23	
		10051	June 1·723	−38·6	5=23	
				−32·3 ±1·1		
H.D. 132525	Ma	6113	1921 May 30·773	−11·1	17=23	All plates weak.
14h 54·5m	6·16	7239	1922 Feb. 27·035	−14·5	15=23	
+04° 58′		7334	Mar. 23·003	− 9·8	15=23	
		7409	April 4·923	−12·8	15=23	
				−12·0 ±0·7		
H.D. 133484	F5	6028	1921 May 12·881	−19·5	9=23	
14h 59·6m	6·43	6092	May 27·798	−24·1	1=23	
+45° 02′		7338	1922 Feb. 26·988	−17·0	1=23	
		7475	April 18·904	−22·7	7=23	
		8962	1923 May 12·855	−19·8	15=23	Weak plate.
		8975	May 20·832	−22·9	1=23	
		10212	1924 July 3·758	−21·0	7=23	
				−21·0 ±0·6		
H.D. 136403	A2	6059	1921 May 21·843	+23·0	11=23	Weak.
15h 15·4m	6·14	7640	1922 June 8·783	+34·6	1=23	
+32° 54′		7692	June 22·765	− 5·7	1=23	
		8789	1923 April 4·987	+23·3	1=23	Binary.
		8859	April 22·918	+21·9	1=23	
		9999	1924 May 21·818	−77·5	1=23	
		10052	June 1·774	− 8·4	5=23	
H.D. 137389	B9	8628	1923 Feb. 28·067	−16·3	3	
15h 20·7m	5·80	8909	May 4·907	−25·4	6	
+62° 23′		8982	May 23·821	−31·7	6	
		9117	July 1·739	−23·5	3	
		9211	July 27·742	−25·4	2	
				−24·5 ±1·6		
H.D. 138213	Ao	7246	1922 Feb. 27·071	−26·6	21	Binary. Orbit under
15h 25·6m	5·96	7345	Mar. 24·987	−16·6	22	investigation.
+47° 35′		7476	April 18·948	−11·5	18	
		7565	May 9·849	− 5·4	17	

INDIVIDUAL MEASURES OF 48 STARS—Continued

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
H.D. 139906	G5	9992	1924 May 20·849	−15·9	11=23	
15h 35·7m	5·94	10082	June 7·809	−14·1	9=23	
+50° 45′		10214	July 3·798	−14·4	7=23	
		10357	July 28·718	−13·8	1=23	
				−14·5 ±0·3		
H.D. 140815	Ko	6114	1921 May 30·833	+12·9	17=23	
15h 40·6m	6·46	7591	1922 May 15·866	+16·2	15=23	
+01° 10′		7613	May 26·845	+13·4	15=23	
		8882	1923 April 24·889	+13·1	17=23	
		8963	May 12·893	+10·8	11=23	
				+13·3 ±0·6		
H.D. 144889	Ko	6093	1921 May 27·837	+54·9	17=23	
16h 03·0m	6·34	7410	1922 April 4·973	+57·4	13=23	
+22° 06′		8759	1923 Mar. 29·662	+58·6	15=23	
		8883	April 24·934	+57·1	13=23	
		10215	1924 July 3·827	+52·5	15=23	
				+56·1 ±0·7		
H.D. 153882	Aop	7642	1922 June 8·850	−32·2	1=23	
16h 57·0m	6·16	8861	1923 April 22·989	−33·8	1=23	
+15° 05′		8984	May 23·900	−34·2	1=23	
		9096	June 27·730	−35·0	1=23	
		10000	1924 May 21·859	−31·6	1=23	
				−33·4 ±0·4		
H.D. 154431	A3	7477	1922 April 18·996	−49·5	9	Binary.
17h 00·3m	6·01	7566	May 9·888	−35·6	6	
+34° 56′		7614	May 26·898	+34·1	4	
				−41·3		
		9253	1923 Aug. 6·722	+38·3	9	
				−61·7		
H.D. 156208	Ao	7734	1922 June 27·749	− 4·2	9	Very poor lines, the interagreement of which is poor.
17h 11·2m	6·02	9272	1923 Aug. 10·690	− 2·2	8	
+02° 18′		9945	1924 May 10·897	+ 2·4	4	
		10343	July 23·726	−19·8	4	
		10358	July 28·767	−18·0	6	
				−8·4 ±3·0		
H.D. 157358	F8	8876	1923 April 23·992	+ 3·5	7=23	This star is possibly a binary although the interagreement of the individual lines is very poor. 4th plate ½ wt. Last plate wt. 2.
17h 17·7m	6·33	8949	May 7·869	+ 3·8	13=23	
+28° 51′		9289	Aug. 14·746	−13·5	7=23	
		10229	1924 July 5·818	−14·4	17=23	
		10403	July 31·720	−13·3	13=23	
		10683	Sept. 11·664	− 9·2	1=23	
				−6·9 ±3·3		
H.D. 165524	Ko	7691	1922 June 20·871	−36·5	11=23	
18h 01·3m	6·43	8041	Sept. 5·673	−35·5	11=23	
+21° 38′		8884	1923 April 24·978	−34·5	13=23	
		10444	1924 Aug. 5·781	−35·5	13=23	
		10685	Sept. 11·708	−36·4	9=23	
				−35·7 ±0·2		

INDIVIDUAL MEASURES OF 48 STARS—Concluded

Star α, δ, (1900)	Type Mag.	Plate	Date G.M.T.	Rad. Vel.	Regions Lines	Remarks
H.D. 172380	Mb	8121	1922 Sept. 15·644	−14·3	9=23	
18^h $34{\cdot}8^m$	6·14	8167	Sept. 23·646	−19·5	7=23	
+39° 35′		9272	1923 Aug. 10·718	−22·2	9=23	
		10404	1924 July 31·764	−22·1	15=23	
		10561	Aug. 28·750	−15·7	13=23	
				−18·8 ±1·1		
H.D. 178619	F5	9213	1923 July 27·819	− 3·9*	14	Binary.
19^h $04{\cdot}2^m$	6·46	9244	Aug. 4·747	+78·5	13	
+16° 42′				−75·2		
		9266	Aug. 8·751	+ 7·0	18	
		9291	Aug. 14·805	+101·8	9	
				−68·3		
H.D. 189066	B3	9197	1923 July 21·834	−25·7	8	
19^h $53{\cdot}1^m$	6·04	9213	July 27·860	−18·5*	8	
+35° 59′		9245	Aug. 4·781	−21·1	7	
		9256	Aug. 6·786	−26·9	8	
				−23·0 ±1·3		
H.D. 205114–5	Ko	6334	1921 July 21·753	−20·0	1=23	Suspected binary. The general appearance of this star is similar to that of an F6.
21^h $28{\cdot}1^m$	A3					
+52° 11′	6·20	8124	1922 Sept. 15·772	−26·4	1=23	
		8168	Sept. 23·777	−28·9*	1=23	
		8293	Nov. 21·571	−22·8	13=23	
		10687	1924 Sept. 11·759	−17·2*	7=23	
H.D. 212222	B3	6347	1921 July 30·921	−10·0	7	
22^h $17{\cdot}6^m$	6·27	8043	1922 Sept. 5·805	−18·4	9	
+41° 36′		8125	Sept. 15·802	−22·3	5	
		8227	Oct. 10·797	−22·5	10	
		10219	1924 July 3·907	−14·5	9	
		10386	July 23·871	−17·5	8	
				−17·5 ±1·3		
H.D. 216672	Mb	8126	1922 Sept. 15·836	+ 3·8	17=23	Weak plate. Half weight.
22^h $49{\cdot}7^m$	6·48	8452	Nov. 30·599	+11·4	15=23	
+16° 24′		10573	1924 Aug. 30·828	+10·3	13=23	
		10688	Sept. 11·790	+13·5	15=23	
				+10·6 ±1·1		
H.D. 224165	Ko	8127	1922 Sept. 15·880	−13·2	11=23	
23^h $50{\cdot}6^m$	6·13	8169	Sept. 23·845	−23·6*	11=23	
+46° 48′		8453	Nov. 30·657	−16·9	1=23	
		10529	1924 Aug. 22·878	−10·9	11=23	
		10544	Aug. 26·866	−18·0	9=23	
		10562	Aug. 28·855	−16·1	11=23	
		10601	Sept. 2·857	−18·7	11=23	
				−17·0 ±1·1		

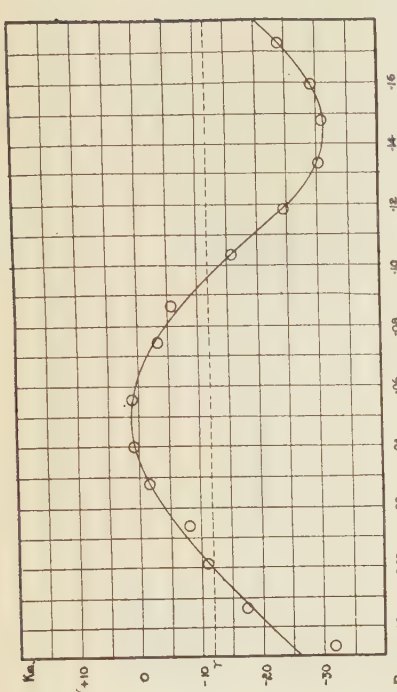

Fig. 2. September 17, 1923.

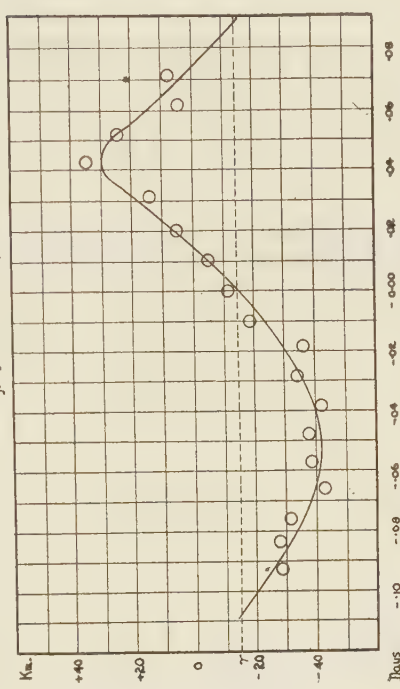

Fig. 4. July 31, 1924.

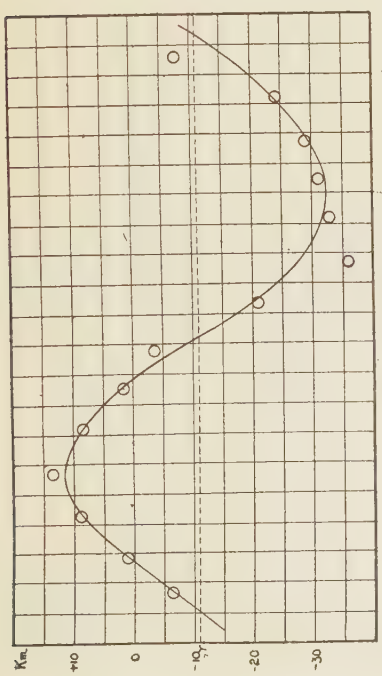

Fig. 1. November 22, 1922

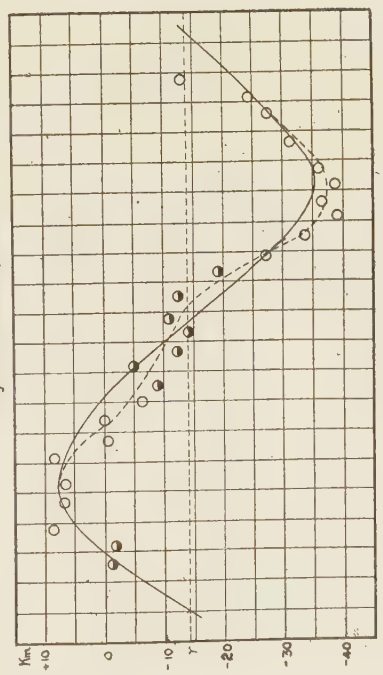

Fig. 3. July 28, 1924

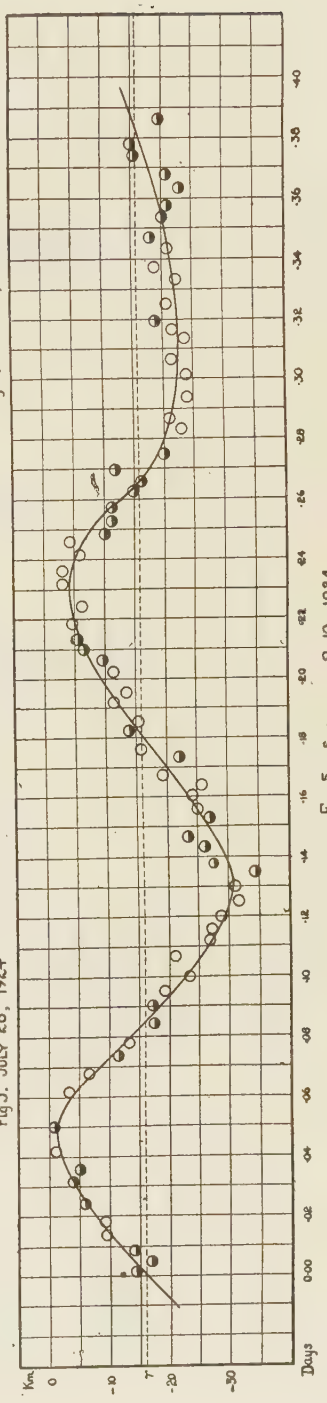

Fig 5. September 9-10, 1924.

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FOUR DOUBLE-LINED F-TYPE SPECTROSCOPIC BINARIES

By W. E. Harper

GENERAL ABSTRACT

During the past two or three years observations have been secured incidentally of several spectroscopic binaries. Of the four here treated two were discovered to be binaries at other observatories and two at our own. The four investigated, moreover, are all of F-type with the additional interesting feature of showing the spectra of both components. In two of these the spectrum lines are nearly of equal strength, in the other two, one set of lines is on the average two or three times as intense as the other.

The stars under consideration are given in the following table.

Star	α 1900	δ 1900	Vis. Mag.	Type
	h m	° ′		
63 Geminorum	7 21·8	+ 21 39	5·27	F5
σ_2 Cor. Bor.	16 10·9	34 07	5·76	F8
H.R. 7267	19 04·2	16 42	6·46	F5
H.R. 8257	21 30·9	+ 27 46	6·35	F3

In spectra of this type with numerous lines it is exceedingly difficult, when both spectra are showing, to assign a value for the relative intensities of the lines due to each component. As the lines oscillate back and forth the general appearance of the resulting spectrum undergoes great changes due to the blending, either partial or complete, of neighbouring lines. This is especially true where the component spectra are of unequal intensity.

14778—1

In the star H.R. 7267 the lines have about equal strength and it turns out that the semi-amplitudes of velocity variation and consequently the masses are equal. In the star σ_2 Coronae Borealis there is sufficient difference in the spectra to distinguish between them and corresponding differences in the masses are shown. In the other two stars the mass of the secondary is in each case about 0·8 times that of the main component, but the spectrum lines for the main components are from two to three times as strong as those of the secondaries. There are a few lines, such as λ 4215, which are fairly well isolated and these suggest a ratio of two or three to one. When a spectrum showing the lines completely superposed is studied in connection with those having the lines resolved, the resulting character of the spectrum is fairly well accounted for on the assumption that the general intensities of the lines of the main component are two and one-half times that of the secondary. There would seem, however, to be some slight evidence that this ratio was not constant as if the lines of a component increased in strength when that component was approaching us in its orbit.

Reproductions of the spectra of the four stars are given at the end. For H.R. 7267 only one spectrum is shown; in the case of the other three, two spectra are shown of each, the upper one in each case having the stronger component to the red, and the lower one *vice versa*.

63 Geminorum

Abstract.—Thirty-nine spectrograms of this binary were made the basis of the determination of its spectroscopic elements. The lines of both spectra appear on the plates though with considerable difference of intensity. Measures of both spectra were combined into one least-squares solution which gives practically a circular orbit with a period 1·93265 days.

The star 63 Geminorum (1900 $\alpha = 7\text{h}\ 21{\cdot}8\text{m}$, $\delta = +21^\circ\ 39'$) visual magnitude 5·27 and type F5, was announced as a spectroscopic binary by the Lick Observatory in the *Publications of the Astronomical Society of the Pacific*, June, 1922. No measures were given but the fact was stated of the spectrum showing double lines.

During the three seasons 1923, 1924 and 1925 a total of 39 plates have been secured here with the single-prism equipment, giving a dispersion at Hγ of 29 angstroms per millimetre. On all but 12 of these both sets of lines were measured, the micrometer engine being used entirely. From 12 to 27 lines were measured on each plate as being due to the main component. The number of those due to the secondary varied greatly from plate to plate and while in a few cases as many as 12 were measured, there were other times when only 1 or 2 could be relied upon. The average was nearly 6. The intensities of the lines of the main component are on the average probably two or three times as great as of those due to the secondary, whilst the ratios of the masses are only 117 to 95.

The data of the plates are given in the following table in which the phases are based upon the final value of periastron. The time quoted is Greenwich Mean Time in the sense used prior to 1925. The residuals are scaled from a curve representing the final elements and are given for all plates excepting where the lines are partially superposed. The probable error of a plate is $\pm 4{\cdot}75$ km. per sec. for the main component and $\pm 7{\cdot}03$ for the secondary.

OBSERVATIONS OF 63 GEMINORUM

Plate	Date	Julian Date	Phase	Component I			Component II		
				Vel.	Wt.	O-C	Vel.	Wt.	O-C
8496	1923 Jan. 10	2,423,430·893	0·845	+ 11·7	2	.....	.....	.....	.....
8667	Mar. 16	3,495·805	0·047	+ 1·5	2	.....	.....	.....	.....
8679	" 19	3,498·747	1·056	+ 70·0	2	− 4·0	− 43·0	1	− 7·0
8724	" 26	3,505·847	0·426	− 77·3	4	− 6·8	+144·4	2	+ 3·0
8778	April 2	3,512·699	1·480	+117·4	2	+ 4·0	− 68:	½	+19·0
8810	" 9	3,519·748	0·798	+ 5·2	2	.....	.....	.....	.....
8865	" 23	3,533·712	1·234	+107·6	2	− 1·6	− 78·3	1	+ 2·2
9571	Oct. 27	3,720·050	0·104	− 31·8	3	− 2·8	+ 93·1	2	+ 3·1
9707	1924 Mar. 3	3,848·758	1·258	+119·7	3	+ 7·3	− 78·2	1	+ 4·8
9722	" 10	3,855·741	0·510	− 64·3	3	− 0·3	+147·8	2	+13·3
9766	" 17	3,862·758	1·729	+ 39·5	2	−22·5	− 16·0	1	+ 5·2
9786	" 22	3,867·773	0·946	+ 30·5	2	.....	.....	.....	.....
9795	" 24	3,869·661	0·901	+ 26·6	2	.....	.....	.....	.....
9830	April 7	3,883·738	1·450	+122·6	3	+ 7·0	− 81·0	1	+ 9·0
9837	" 14	3,890·701	0·682	− 30·0	2	+ 2·4	+101·1	2	+ 4·1
10790	Sept. 27	4,056·039	1·745	+ 60·6	1	+ 2·0	− 9·6	1	+ 6·4
10860	Oct. 10	4,069·044	1·222	+117·6	2	+10·0	− 51·4	1	+27·0
11102	Dec. 23	4,143·936	0·740	− 9·9	4	+ 9·0	+ 76:	½	− 3·0
11176	1925 Jan. 23	4,174·815	0·697	− 27·0	3	+ 2·5	.....	.....	.....
11215	Feb. 14	4,196·757	1·380	+123·3	4	+ 5·3	− 91·3	1	− 0·3
11227	" 23	4,205·768	0·727	− 16·0	4	.....	.....	.....	.....
11240	Mar. 5	4,215·780	1·076	+ 65·8	2	−13·0	− 25·9	1	+16·0
11261	" 6	4,216·743	0·106	− 25·6	3	+ 4·0	+ 94·2	2	+ 3·2
11308	" 14	4,224·777	0·410	− 70·5	5	0·0	+138·0	1	− 3·6
11321	" 16	4,226·705	0·405	− 68·8	4	+ 1·7	.....	.....	.....
11338	" 19	4,229·767	1·535	+ 96·8	2	− 8·2	− 90·1	2	−12·1
11382	" 30	4,240·677	0·849	+ 22·3	2	+ 6·3	.....	.....	.....
11414	April 6	4,247·645	0·086	− 13·7	4	+10·3	.....	.....	.....
11421	" 6	4,247·749	0·190	− 46·0	2	+ 0·2	.....	.....	.....
11470	" 11	4,252·684	1·260	+114·5	5	+ 2·0	− 89·0	2	− 5·5
11484	" 13	4,254·657	1·300	+116·6	4	+ 0·6	− 84·3	2	+ 2·8
11504	" 16	4,257·725	0·503	− 70·4	2	− 4·9	+118·9	1	−16·6
11519	" 20	4,261·661	0·574	− 58·5	3	− 4·5	+ 93·8	1	−30·0
11550	April 23	4,264·717	1·697	+ 67·5	3	+ 2·6	.....	.....	.....
11586	May 4	4,275·695	1·079	+ 62·4	3	−16·6	− 53·4	1	−11·0
11604	" 11	4,282·688	0·341	− 72·6	4	− 5·0	−138·0	2	0·0
11605	" 11	4,282·706	0·359	− 70·8	4	− 1·8	+139·5	1	0·0
11619	" 14	4,285·696	1·417	+122·8	2	+ 5·0	−104·9	1	−14·4
11629	" 15	2,424,286·704	0·492	− 75·5	3	− 9·0	+132:	1	− 4·5

The period was found by the writer to be in the neighbourhood of 2 days. I am indebted to Mr. W. H. Christie, summer assistant at this Observatory, for obtaining the exact number of cycles so as to connect up the three seasons' observations. With the adopted value of the period, namely 1·93265 days, the observations were grouped into 24 normal places, numbers 1 to 14 representing the main, and numbers 15 to 24 the secondary component.

NORMAL PLACES

	Mean Phase	Vel.	Wt.	Final (O-C)		Mean Phase	Vel.	Wt.	Final (O-C)
1	0·084	− 14·22	0·9	+ 9·73	13	1·508	+107·10	0·4	− 2·60
2	0·138	− 37·48	0·5	− 0·29	14	1·716	+ 56·72	0·6	− 8·71
3	0·350	− 71·70	0·8	− 2·73	15	0·105	+ 93·65	0·4	+ 3·25
4	0·413	− 72·18	1·3	− 1·89	16	0·347	+138·50	0·3	− 0·85
5	0·496	− 73·46	0·5	− 7·52	17	0·421	+142·27	0·3	+ 1·28
6	0·542	− 61·40	0·6	− 0·66	18	0·498	−125·25	0·2	−10·36
7	0·691	− 28·60	0·5	+ 3·20	19	0·531	+129·80	0·3	− 1·37
8	0·733	− 13·00	0·8	+ 7·94	20	0·694	+ 96·16	0·2	+ 3·42
9	0·868	+ 19·26	1·0	+ 0·74	21	1·070	− 40·77	0·3	+ 0·02
10	1·072	+ 65·54	0·7	−12·09	22	1·416	− 92·40	0·3	− 1·15
11	1·262	+115·52	1·6	+ 2·51	23	1·524	− 85·68	0·2	− 7·28
12	1·412	+123·00	0·9	+ 4·98	24	1·737	− 12·90	0·2	+ 6·16

From graphical methods the following were adopted as preliminary values of the elements.

$$
\begin{aligned}
P &= 1{\cdot}93265 \text{ days} \\
e &= 0{\cdot}03 \\
\omega_1 &= 105^\circ \\
\omega_2 &= 285^\circ \\
\gamma &= +24{\cdot}76 \text{ km/sec.} \\
K_1 &= 98{\cdot}0 \text{ km/sec.} \\
K_2 &= 115{\cdot}0 \text{ km/sec.} \\
T &= \text{J.D. } 2{,}423{,}430{\cdot}048
\end{aligned}
$$

The period was taken as sufficiently well determined from the three years' observations and owing to the very low value of the eccentricity it was necessary also to consider T, the time of periastron passage, as fixed. For the sake of homogeneity the following substitutions were made in the observation equations connecting the remaining elements with the residuals.

$$
\begin{aligned}
x &= \delta\gamma \\
y &= \delta K_1 \\
z &= \delta K_2 \\
u &= 100 \cdot \delta e \\
v &= -100 \cdot \delta\omega
\end{aligned}
$$

OBSERVATION EQUATIONS

1	1·000x	− ·532y	+ ·000z	− ·743u	+ ·863v	−13·13	= 0
2	1·000	− ·680	+ ·000	− ·933	+ ·754	− 4·38	
3	1·000	−1·001	+ ·000	− ·467	+ ·141	− 1·61	
4	1·000	−1·004	+ ·000	− ·074	− ·062	− 1·43	
5	1·000	− ·943	+ ·000	+ ·445	− ·319	+ 5·83	
6	1·000	− ·880	+ ·000	+ ·680	− ·451	− ·06	
7	1·000	− ·563	+ ·000	+ ·970	− ·787	− 1·79	
8	1·000	− ·449	+ ·000	+ ·902	− ·852	− 6·22	
9	1·000	− ·048	+ ·000	+ ·325	− ·951	+ ·82	
10	1·000	+ ·545	+ ·000	− ·771	− ·788	+12·65	
11	1·000	+ ·915	+ ·000	− ·852	− ·350	− 1·07	
12	1·000	+ ·989	+ ·000	− ·097	+ ·108	− 1·29	
13	1·000	+ ·916	+ ·000	+ ·498	+ ·404	+ 7·45	
14	1·000	+ ·456	+ ·000	+ ·946	+ ·897	+12·75	
15	1·000	+ ·000	+ ·592	+ ·963	− ·967	− ·83	
16	1·000	+ ·000	+1·000	+ ·569	− ·178	+ 1·24	
17	1·000	+ ·000	+1·001	+ ·024	+ ·103	− 2·41	
18	1·000	+ ·000	+ ·940	− ·536	+ ·383	+ 7·59	
19	1·000	+ ·000	+ ·897	− ·738	+ ·493	− 1·90	
20	1·000	+ ·000	+ ·555	−1·135	+ ·929	− 7·60	
21	1·000	+ ·000	− ·539	+ ·896	+ ·929	+ 3·53	
22	1·000	+ ·000	− ·988	+ ·084	− ·142	+ 3·52	
23	1·000	+ ·000	− ·894	− ·688	− ·529	+ 7·61	
24	1·000	+ ·000	− ·391	−1·043	−1·088	− 7·32	

From these there resulted the normal equations

13·800x	−1·238y	+ ·690z	− ·710u	+1·731v	− 1·796	=	0
	6·718	+ ·000	−1·225	− ·061	+19·252		
		1·789	+ ·015	+ ·129	− 2·882		
			6·442	−1·268	+13·938		
				5·350	− 6·526		

which gave corrections to the preliminary elements as follows:—

$$\begin{aligned} \delta\gamma &= -0{\cdot}38 \text{ km.} \\ \delta K_1 &= -3{\cdot}44 \text{ km.} \\ \delta K_2 &= +1{\cdot}76 \text{ km.} \\ \delta e &= -{\cdot}028 \\ \delta\omega &= -0°{\cdot}16 \end{aligned}$$

Hence the final values of the elements with their probable errors attached are the following. In computing the latter the probable error of a normal place of average weight has been used,—

$$r = \pm{\cdot}6745 \sqrt{\frac{\Sigma pvv}{n-\mu}} \frac{n}{\Sigma p}$$

Final Elements

Period	P	=	1·93265 days
Eccentricity	e	=	·002 ±·017
Longitudes of apses	ω_1	=	104°·84 ±1°·07
	ω_2	=	284°·84 ±1°·07
Semi-amplitudes of velocity	K_1	=	94·56 ±1·70 km./sec.
	K_2	=	116·76 ±3·22 km./sec.
Velocity of system	γ	=	+24·38 ±1·18 km./sec.
Periastron passage	T	=	J.D. 2,423,430·048
Projection of semi-major axes	$a_1 \sin i$	=	2,513,000 km.
	$a_2 \sin i$	=	3,103,000 km.
	$m_1 \sin^3 i$	=	1·05 ⊙
	$m_2 \sin^3 i$	=	0·85 ⊙

These elements reduced the sum of the squares of the residuals for the normal places from 491 to 436, a matter of 11 per cent. The graph accompanying represents the final elements, the full circles representing the main and the broken ones the secondary component.

June, 1925.

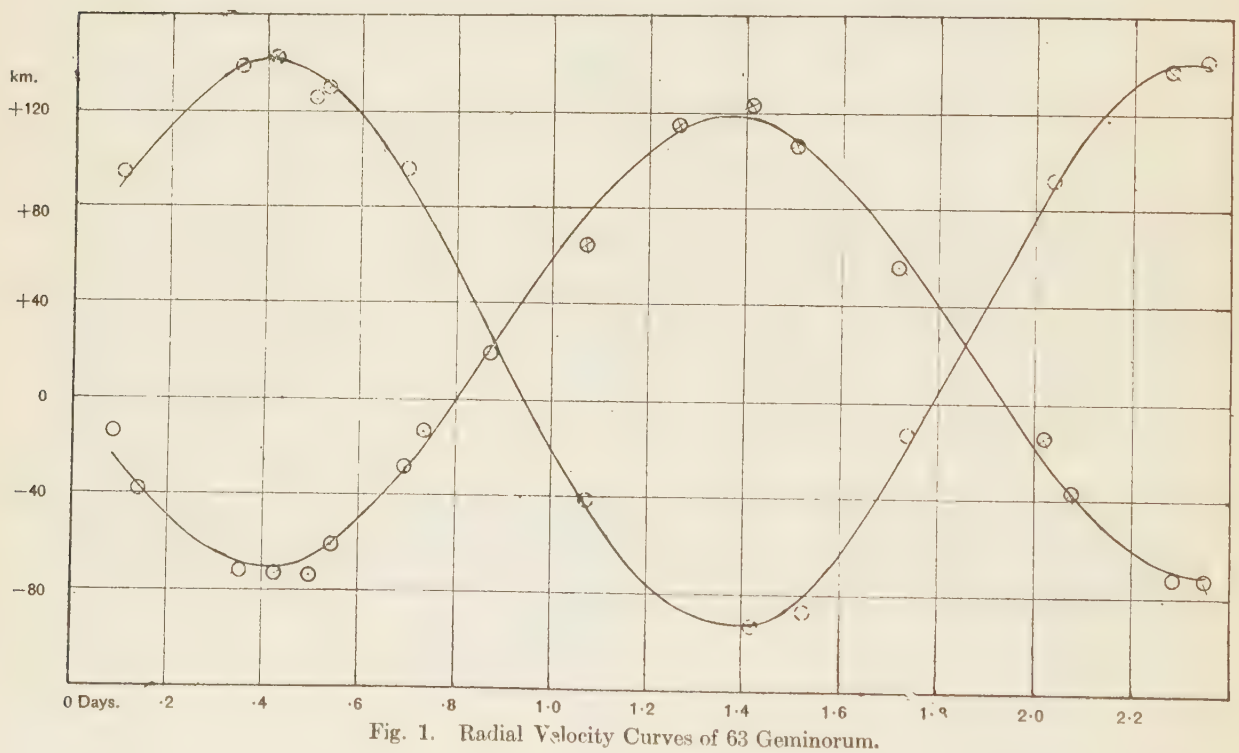

Fig. 1. Radial Velocity Curves of 63 Geminorum.

σ_2 Coronae Borealis

Abstract.—Seventy-four single-prism spectrograms of this double-line F-type star have been made at this observatory during the past four years. The semi-amplitudes of velocity for the components are respectively 60 and 68 km/sec. and thus for a considerable portion of the period the lines are not resolved. The period obtained of 7·974 days, while giving larger residuals than would be expected, seems to be the only possible one. The component spectra, while nearly alike, can be distinguished and this value of the period throws all observations on the right branch of the curve.

The star σ_2 Coronae Borealis (1900 $\alpha = 16\text{h } 10{\cdot}9\text{m}$, $\delta = +34^\circ\ 07'$) whose visual magnitude is 5·76 and type F8, was discovered to be a spectroscopic binary by Adams at Mount Wilson from four plates taken in 1914. Announcement was made of a relative displacement of the component spectra of 140 km. and through the kindness of Dr. Adams the writer has been furnished with the measures of their four plates and these appear in the table of observations.

The star was placed under observation here in the summer of 1922 and from the observations of that and the following year it appeared the period was in the neighbourhood of eight days. The best value was a little over the eight days, namely 8·07, but this threw the two observations of 1922 showing double lines on the wrong branch of the curve. It seemed necessary to decrease the period to 7·97 days so that the components would fall on the proper branch of the curve. Ten more observations were secured in 1924 when further trials for a more satisfactory period were made without securing one. Thirty-odd plates have been made this season with additional trials for a more satisfactory period but without avail. Periods in the neighbourhood of a day seem to be out of the question, and the value 7·974 adopted to best represent all the years seems to be the only possible one to accept. With this value all measures, including the early Mount Wilson, fall on the proper branch of the curve yet the agreement is extremely ragged, the probable error of a plate being, for component I, $\pm 6{\cdot}0$, and for component II $\pm 6{\cdot}6$ km/sec. The lines are, when fully resolved, apparently well suited for measurement though, owing to their number, very few are unaffected by neighbouring lines in spectra of this dispersion. Taken in conjunction with the fact that the lines are properly resolved for less than half the period this vitiation by neighbouring lines seems the only valid explanation of the large residuals present.

14778—2½

OBSERVATIONS OF σ_2 CORONAE BOREALIS

Plate	Date	Julian Date	Phase	Component I			Component II		
				Vel.	n	O-C	Vel.	n	O-C
Mount Wilson	1914 June 10	2,420,294·925	4·689	−11·0					
	July 6	0,320·829	6·671	+37·0			−77·0		
	Aug. 10	0,355·688	1·660	−77·0			+61·0		
	Sept. 9	0,385·662	7·712	−11·0					
7649	1922 June 9	3,215·838	7·118	+ 3·4	4				
7789	July 10	3,246·738	6·122	+50·6	9	+ 1·6	−85·2	7	− 6·5
8092	Sept. 13	3,311·664	7·256	+40·0	12	+13·0	−64·7	10	−12·2
8874	1923 April 23	3,533·955	6·275	+49·7	10	+ 0·7	−76·2	7	+ 3·0
8948	May 7	3,547·830	4·202						
8969	" 19	3,559·867	0·191	−24·3	9				
8979	" 22	3,562·824	3·248	−15·6	7				
9007	June 3	3,574·867	7·317	+13·4	9	−10·6	−55·3	2	− 5·5
9024	" 6	3,577·826	2·302	−64·3	6	+ 2·7	+59·2	6	+ 7·0
9041	" 12	3,583·807	0·309	−23·0	8				
9075	" 18	3,589·862	6·364	+50·7	13	+ 2·0	−77·9	12	+ 1·0
9081	" 25	3,596·727	5·255	+52·1	13	+16·1	−77·0	10	−13·0
9090	" 26	3,597·765	6·293	+44·3	13	− 4·8	−72·8	12	+ 3·6
9118	July 1	3,602·812	3·366						
9120	" 2	3,603·726	4·280						
9121	" 3	3,604·732	5·286	+43·8	13	+ 8·8	−78·9	13	−16·9
9132	" 9	3,610·712	3·292	−17·6	14				
9168	" 14	3,615·760	0·366	−18·2	10				
9179	" 19	3,620·749	5·355	+37·5	12	− 0·7	−74·6	10	− 7·6
9186	" 20	3,621·709	6·315	+43·3	12	− 5·7	−77·2	12	+ 1·8
9195	" 21	3,622·772	7·378	+31·6	10	+10·0	−66·8	5	−20·0
9203	" 22	3,623·711	0·343	−23·3	9				
9231	Aug. 2	3,634·707	3·365	−47·1	7	−12·6	+29·0	5	+11·2
9239	" 3	3,635·702	4·360	−16·4	11				
9246	" 5	3,637·697	6·355	+43·8	15	− 5·0	−84·8	13	− 5·8
9252	" 6	3,638·695	7·353	+24·6	7	+ 2·6	−55·5	5	− 7·5
9288	" 14	3,646·710	7·394	+30·9	11	+10·4	−63·4	5	−17·9
9302	" 17	3,649·675	2·385	−76·1	13	−11·1	+51·0	6	+ 0·5
9363	" 29	3,661·667	6·403	+48·8	14	+ 0·3	−81·5	11	− 3·0
9409	Sept. 16	3,679·640	0·454	− 4·8	16				
9438	" 22	3,685·630	6·444	+52·1	11	+ 3·9	−79·2	11	− 1·2
9806	1924 Mar. 24	3,869·987	7·399	− 9·8	10				
9940	May 9	3,915·893	5·461	+49·5	9	+ 9·0	−74·3	8	− 5·3
10225	July 4	3,971·755	5·505	+42·5	10	+ 1·0	−77·2	9	− 5·0
10238	" 7	3,974·709	0·485	−41·7	3	− 4·7	+27·6	2	+ 8·5
10296	" 14	3,981·735	7·511	− 3·6	10				
10533	Aug. 25	4,023·673	1·605	−59·5	7	+10·5	+40·9	5	−16·6
10622	Sept. 6	4,035·660	5·618	+30·6	7	−13·4	−60·4	6	+12·6
10633	" 8	4,037·662	7·620	+31·0	9	+21·6	−61·6	9	−28·6
10724	" 15	4,044·682	6·666	+50·2	13	+ 5·0	−73·9	8	0·0
10776	" 26	4,055·628	1·664	−49·8	12	+18·0	+25·0	3	−23·0
11281	1925 Mar. 6	4,217·051	3·607	−13·4	12				
11316	" 14	4,224·987	3·569	−11·8	12				
11428	April 6	4,247·950	2·610	−55·2	14	+ 4·8	+48·2	7	+ 3·7
11468	" 9	4,250·968	5·628	+48·8	12	+ 4·4	−78·3	12	− 5·0
11502	" 13	4,254·957	1·643	−71·8	20	− 1·8	+55·9	10	− 1·6
11509	" 16	4,257·933	4·619	+28·1	5	+12·0	−50·3	5	−11·3

OBSERVATIONS OF σ_2 CORONAE BOREALIS—*Concluded.*

Plate	Date	Julian Date	Phase	Component I			Component II		
				Vel.	n	O-C	Vel.	n	O-C
11591	1925 May 4	4,275·884	6·622	+32·8	16	−13·2	−67·9	7	+ 7·1
11610	" 11	4,282·831	5·595	+52·2	18	+ 8·2	−78·6	13	− 5·8
11624	" 14	4,285·814	0·604	−60·4	2	−17·4	+33·8	2	+ 8·8
11633	" 15	4,286·833	1·623	−70·5	14	− 0·5	+59·7	7	+ 2·2
11657	" 23	4,294·791	1·607	−70·2	11	− 0·2	+53·4	7	− 4·1
11663	" 24	4,295·830	2·646	−53·1	13	+ 5·7	+39·1	4	− 4·4
11665	" 25	4,296·695	3·511	− 0·9	19				
11673	" 25	4,296·964	3·780						
11715	June 14	4,316·703	7·571	−21·2	8				
11717	" 14	4,316·750	7·618	−13·3	9				
11731	" 17	4,319·826	2·720	−69·8	14	0·0	+50·9	11	+ 9·9
11736	" 18	4,320·774	3·668	−13·2	12				
11750	" 20	4,322·783	5·677	+45·2	11	+ 0·2	−77·5	11	− 3·6
11766	" 22	4,324·807	7·701						
11773	" 24	4,326·789	1·709	−67·7	14	+ 2·8	+56·5	9	− 1·7
11780	" 26	4,328·802	3·722	−23·6	9				
11796	" 29	4,331·871	6·791						
11804	July 1	4,333·733	0·679						
11833	" 4	4,336·767	3·713	−50·8	12		+44·8	3	
11836	" 5	4,337·750	4·696						
11840	" 6	4,338·750	5·696	+51·3	16	+ 6·0	−70·8	12	+ 3·2
11852	" 8	4,340·793	7·739						
11877	" 11	4,343·440	2·412	−76·5	13	−11·0	+48·2	13	− 1·8
12159	Aug. 26	4,389·704	0·832	−13·5	12				
12246	Sept. 11	4,405·654	0·834						
12330	" 21	2,424,415·647	2·853	−69·7	14	−17·4	+60·2	10	+22·2

In the foregoing table the phases are reckoned from the final value adopted for periastron passage, namely J.D. 2,423,216·694, with the period 7·974 days. It is with considerable reluctance that this value for the period has been accepted owing to the large residuals of many of the plates, but much time has been spent in unsuccessful efforts to secure a better one. The number of lines measured is given in each case and the residuals, given for those spectra either wholly or partially resolved, are scaled from the curve representing the final elements. Where no velocity is entered the lines are partially superposed rendering measurement inadvisable, but eye estimates indicate that the result would agree with the curve.

NORMAL PLACES

	Mean Phase	Mean Vel.	Wt.	O-C		Mean Phase	Mean Vel.	Wt.	O-C
1	6·329	+48·0	0·9	− 1·1	11	5·519	+46·7	1·0	+ 4·7
2	6·644	+41·5	0·3	− 3·8	12	6·329	−79·8	0·9	− 0·9
3	7·386	+28·6	0·4	+ 8·2	13	6·644	−70·9	0·15	+ 3·6
4	7·938	−14·8	0·9	− 6·2	14	7·400	−62·2	0·25	−16·8
5	0·544	−51·0	0·05	−11·4	15	0·544	+30·7	0·05	+ 8·2
6	1·645	−65·9	0·8	+ 4·4	16	1·645	+51·4	0·4	− 6·3
7	2·399	−73·9	0·3	− 9·5	17	2·403	+51·6	0·2	+ 0·9
8	2·707	−62·0	0·5	− 5·0	18	2·732	+52·1	0·3	+10·5
9	3·648	−15·3	0·7	+ 8·9	19	4·619	−50·3	0·05	−11·2
10	4·619	+28·1	0·05	+13·8	20	5·501	−66·9	0·9	+ 3·4

The observations were grouped into twenty normal places as above, eleven representing component I and nine component II. Preliminary elements were obtained as shown in the table at the end and a set of observation equations built up connecting the residuals for the normal places with the elements. The period was omitted and owing to the low value of the eccentricity it was necessary to omit periastron passage also. In the observation equations of the Lehmann-Filhés form adapted to double-line spectra the following substitutions were made.

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K_1 \\ z &= \delta K_2 \\ u &= 100 \cdot \delta e \\ v &= -100 \cdot \delta\omega \end{aligned}$$

OBSERVATION EQUATIONS

1	1·000x	+ ·984y	+ ·000z	+ ·211u	+ ·137v	+ 1·0 = 0
2	1·000	+ ·907	+ ·000	+ ·472	+ ·287	+ 2·8
3	1·000	+ ·488	+ ·000	+ ·532	+ ·563	− 9·8
4	1·000	+ ·031	+ ·000	+ ·039	+ ·640	+ 5·7
5	1·000	− ·455	+ ·000	− ·506	+ ·573	+12·2
6	1·000	− ·984	+ ·000	− ·211	+ ·137	− 5·1
7	1·000	− ·916	+ ·000	+ ·443	− ·213	+ 7·0
8	1·000	− ·800	+ ·000	+ ·578	− ·336	+ 2·2
9	1·000	− ·240	+ ·000	+ ·278	− ·562	−10·3
10	1·000	+ ·437	+ ·000	− ·470	− ·518	−12·4
11	1·000	+ ·899	+ ·000	− ·476	− ·237	− 2·9
12	1·000	+ ·000	− ·984	− ·232	− ·151	+ 2·9
13	1·000	+ ·000	− ·907	− ·519	− ·316	− 0·9
14	1·000	+ ·000	− ·479	− ·578	− ·622	+19·1
15	1·000	+ ·000	+ ·455	+ ·556	− ·630	−11·2
16	1·000	+ ·000	+ ·984	+ ·232	− ·151	+ 3·5
17	1·000	+ ·000	+ ·915	− ·492	+ ·237	− 1·3
18	1·000	+ ·000	+ ·789	− ·640	+ ·378	−10·2
19	1·000	+ ·000	− ·437	+ ·516	+ ·570	+10·0
20	1·000	+ ·000	− ·893	+ ·535	+ ·269	− 3·9

These resulted in the normal equations,

$$\begin{array}{rrrrrrrrr}
8{\cdot}200x & - & {\cdot}160y & -1{\cdot}128z & + & {\cdot}837u & + & {\cdot}473v & -3{\cdot}680 & = & 0 \\
 & & 2{\cdot}702 & + & {\cdot}000 & + & {\cdot}144 & + & {\cdot}460 & +2{\cdot}020 & \\
 & & & & 2{\cdot}529 & - & {\cdot}231 & + & {\cdot}083 & -3{\cdot}351 & \\
 & & & & & & 1{\cdot}237 & + & {\cdot}119 & -3{\cdot}566 & \\
 & & & & & & & & 1{\cdot}170 & - & {\cdot}204
\end{array}$$

from which corrections were found as follows:—

$$\begin{aligned}
\delta\gamma &= +{\cdot}37 \text{ km.} \\
\delta K_1 &= -{\cdot}88 \text{ km.} \\
\delta K_2 &= +1{\cdot}77 \text{ km.} \\
\delta e &= +{\cdot}031 \\
\delta\omega &= -0°{\cdot}0
\end{aligned}$$

While the differences between equation and ephemeris residuals were in perfect accord, showing that one solution was sufficient, yet the agreement was not markedly improved, the sum of the squares of the residuals for the normal places being reduced merely from 367 to 358.

ELEMENTS OF ORBIT

Element	Preliminary	Final
P	7·974 days	7·974 days.
e	·05	·081 ±·005
ω_1	90°	90°·0 ±2°·84
ω_2	270°	270°·0 ±2°·84
γ	−11·0 km.	−10·63 km. ±1·94 km.
K_1	61·0 km.	60·12 km. ±3·24 km.
K_2	67·0 km.	68·77 km. ±3·35 km.
T	.....	J.D. 2, 423, 216·694
$a_1 \sin i$	.....	6,570,700 km.
$a_2 \sin i$	.....	7,516,000 km.
$m_1 \sin^3 i$	.....	0·94 ⊙
$m_2 \sin^3 i$	.....	1·07 ⊙

The graph represents the final elements, the broken circles representing component II.

September, 1925.

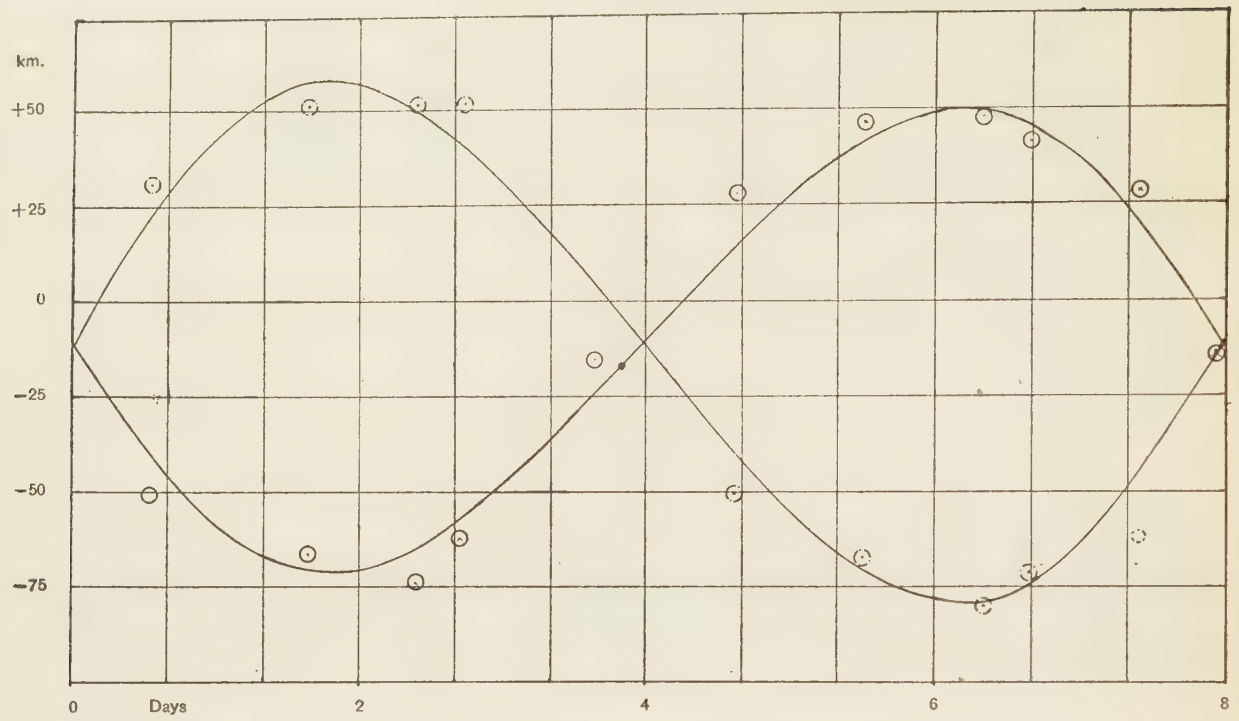

Fig. 2. Radial Velocity Curves of σ_2 Coronae Borealis.

H. R. 7267

Abstract.—Twenty-three spectrograms of which sixteen show the component spectra in about equal intensity, were made the basis of the determination of the elements of the spectroscopic orbit. The period obtained was 4·812 days, eccentricity ·073, and semi-amplitude of both components 86·0 km/sec.

The star H.R. 7267 (1900 $\alpha = 19\text{h}\ 04{\cdot}2\text{m}$, $\delta = +16°\ 42'$, visual magnitude 6·46 and type F5) was discovered to be a spectroscopic binary here by W. H. Christie in the summer of 1923 from four plates, two of which showed double lines. The results of these, modified by the writer's measures of the same plates, appear in the Table of Observations.

In all, thirty spectrograms were secured with the single-prism equipment, giving a dispersion of about 29 angstroms per millimetre at Hγ. Two of these were not measured as the lines were seen to be partially superposed. Five others which were measured were afterwards rejected for the same reason. There remained seven plates showing the lines as single and fairly sharp and sixteen others with the lines sufficiently resolved for measurement, and thus the solution is based upon the equivalent of thirty-seven plates.

In general the spectra are of about equal intensity so that it was difficult to differentiate between them; nevertheless the assignment made when the plates were measured turned out to be correct in about ninety per cent of the cases. The plates were measured on the micrometer engine, about 10 to 15 lines being measured on all but one or two weak plates. The data of the plates are given in the following table, the successive columns

denoting the plate number, the date, the Julian date given in Greenwich Mean Time as used prior to 1925, the phase reckoned from the final elements, the velocities with their corresponding weights and residuals from the final curve. The residuals, in the sense observed minus computed, are shown only for the cases in which the lines are resolved. The probable error of a plate for component I is ±2·89 km. per sec., whilst for component II it is ±3·71 km. per sec.

OBSERVATIONS OF H.R. 7267

Plate	Date	Julian Date	Phase	Component I			Component II		
				Vel.	Wt.	O-C	Vel.	Wt.	O-C
9213	1923 July 27	2,423,628·819	3·009	+ 3·9	2				
9244	Aug. 4	3,636·747	1·313	−73·4	3	−2·0	+78·5	3	−10·5
9266	" 8	3,640·751	0·505	+ 7·0	3				
9291	" 14	3,646·805	1·747	−68·3	3	+1·7	+95·9	3	+ 7·4
9987	1924 May 19	3,925·954	1·800	−66·1	3	+2·6	+86·3	3	+ 0·3
10245	July 7	3,974·843	2·569	+ 2·5	1				
10535	Aug. 25	4,023·731	3·337	+64·0	3	+8·0	−44·7	3	− 6·3
10567	" 29	4,027·726	2·520	−29·5	1	−7·2	+43·2	1	+ 3·3
10592	Sept. 1	4,030·711	0·693						
10624	" 6	4,035·775	0·945	−48·0	2	+4·4	+72·3	2	+ 2·7
10777	" 26	4,055·661	1·583	−72·5	3	+0·7	+88·4	3	− 3·2
10849	Oct. 9	4,068·690	0·176	+ 7·1	3				
10907	" 27	4,086·640	3·690	+84·6	3	+0·9	−61·2	3	+ 4·9
10909	" 31	4,090·624	2·862	+ 5·6	2				
11612	1925 May 11	4,282·949	2·707	+ 6·6	3				
11746	June 18	4,320·890	2·152	−60·6	3	−9·0	+72·5	3	+ 4·1
11843	July 6	4,338·827	0·841						
11901	" 18	4,350·777	3·167	+ 3·3	1				
11967	" 26	4,358·878	1·644	−66·6	3	+5·6	+89·9	3	− 1·1
11978	" 27	4,359·798	2·564	+ 3·9	1				
11990	" 29	4,361·750	4·516	+81·3	3	−2·5	−69·1	3	− 2·9
12003	" 30	4,362·744	0·698	+19·0	1				
12014	" 30	4,362·916	0·870	−45·7	1	+0·8	+78·1	1	+15·0
12029	Aug. 1	4,364·856	2·810	+ 8·0	3				
12042	" 3	4,366·756	4·710	+70·4	3	+3·4	−50·4	3	− 1·0
12049	" 3	4,366·922	0·064	+ 6·8	1				
12059	" 5	4,368·703	1·845	−68·5	3	−1·3	+91·5	3	+ 6·9
12067	" 5	4,368·881	2·023	−60·1	3	−1·3	+77·2	3	+ 1·0
12074	" 6	4,369·788	2·930	+ 9·0	3				
12093	" 12	2,424,375·739	4·069	+99·8	3	+2·0	−73·9	3	+ 6·3

The period was found to be 4·812 days and was deemed sufficiently well determined without including it in the least-squares solution. The observations were grouped according to phase into 22 normal places, 12 representing component I and 10 component II.

NORMAL PLACES

	Mean Phase	Mean Vel.	Wt.	O-C Final		Mean Phase	Mean Vel.	Wt.	O-C Final
1	2·853	+ 6·9	1·3	−2·2	12	2·520	−29·5	0·1	− 7·2
2	3·337	+64·0	0·3	+8·0	13	3·337	−44·7	0·3	− 6·2
3	3·690	+84·6	0·3	+0·9	14	3·690	−61·2	0·3	+ 4·9
4	4·069	+99·8	0·3	+2·0	15	4·069	−73·9	0·3	+ 6·3
5	4·516	+81·3	0·3	−2·5	16	4·516	−69·1	0·3	− 2·9
6	4·710	+70·4	0·3	+3·4	17	4·710	−50·4	0·3	− 1·0
7	0·340	+ 7·0	0·6	−6·9	18	0·920	+74·2	0·3	+ 6·1
8	0·920	−47·2	0·3	+3·3	19	1·313	+78·5	0·3	−10·5
9	1·313	−73·4	0·3	−2·0	20	1·724	+90·4	1·5	+ 1·5
10	1·724	−68·4	1·5	+2·9	21	2·088	+74·8	0·6	+ 2·0
11	2·088	−60·4	0·6	−5·2	22	2·520	+43·2	0·1	+ 3·3

From graphical methods the following preliminary elements were decided upon.

PRELIMINARY ELEMENTS

$$
\begin{aligned}
P &= 4\cdot812 \text{ days} \\
e &= \cdot05 \\
\omega_1 &= 60^\circ \\
\omega_2 &= 240^\circ \\
K_1 &= 84 \text{ km.} \\
K_2 &= 84 \text{ km.} \\
\gamma &= +10\cdot05 \\
T &= \text{J.D. } 2{,}423{,}630\cdot622
\end{aligned}
$$

From these elements there were built up a set of observation equations connecting the residuals with the elements and of the form given in Dominion Observatory Publications, Volume I, page 327. Since the eccentricity was small the element T was dropped from the solution, otherwise two sets of coefficients would be practically the same and the solution therefore indeterminate. For the sake of homogeneity the following substitutions were made:—

$$
\begin{aligned}
x &= \delta\gamma \\
y &= \delta K_1 \\
z &= \delta K_2 \\
u &= 100\cdot\delta e \\
v &= -100\cdot\delta\omega
\end{aligned}
$$

OBSERVATION EQUATIONS FOR H.R. 7267

1	1·000x	+ ·032y	+ ·000z	− ·414u	− ·804v	+5·8	= 0
2	1·000	+ ·590	+ ·000	− ·819	− ·657	−4·4	
3	1·000	+ ·895	+ ·000	− ·412	− ·379	+0·6	
4	1·000	+1·025	+ ·000	+ ·407	+ ·029	−3·7	
5	1·000	+ ·838	+ ·000	+ ·833	+ ·525	−0·9	
6	1·000	+ ·646	+ ·000	+ ·617	+ ·695	−6·1	
7	1·000	+ ·060	+ ·000	− ·389	+ ·876	+8·0	
8	1·000	− ·672	+ ·000	− ·750	+ ·638	+0·8	
9	1·000	− ·935	+ ·000	− ·034	+ ·270	+4·9	
10	1·000	− ·948	+ ·000	+ ·696	− ·157	−1·2	
11	1·000	− ·759	+ ·000	+ ·797	− ·486	+6·6	
12	1·000	− ·355	+ ·000	+ ·217	− ·741	+9·7	
13	1·000	+ ·000	− ·590	+ ·819	+ ·657	+5·1	
14	1·000	+ ·000	− ·895	+ ·412	+ ·379	−4·0	
15	1·000	+ ·000	−1·025	− ·407	− ·029	−2·2	
16	1·000	+ ·000	− ·838	− ·833	− ·525	+8·7	
17	1·000	+ ·000	− ·646	− ·617	− ·695	+6·1	
18	1·000	+ ·000	+ ·672	+ ·750	− ·638	−7·8	
19	1·000	+ ·000	+ ·935	+ ·034	− ·270	+10·0	
20	1·000	+ ·000	+ ·948	− ·696	+ ·157	−0·8	
21	1·000	+ ·000	+ ·759	− ·797	+ ·486	−1·0	
22	1·000	+ ·000	+ ·355	− ·217	+ ·741	−3·4	

From these there resulted the normal equations:—

10·500x	−1·119y	+1·197z	− ·771u	− ·520v	+15·460	= 0
	3·101	+ ·000	−1·034	+ ·324	− 5·815	
		3·098	−1·003	+ ·326	− 3·011	
			4·127	+ ·056	− 6·300	
				2·854	− 6·274	

which gave corrections to the preliminary elements as follows:—

$$\delta\gamma = -1{\cdot}25 \text{ km.}$$
$$\delta K_1 = +2{\cdot}03 \text{ km.}$$
$$\delta K_2 = +2{\cdot}04 \text{ km.}$$
$$\delta e = +{\cdot}023$$
$$\delta\omega = -0^\circ\ 84$$

Hence the final values of the elements with their probable errors attached are the following:—

FINAL ELEMENTS

P	=	4·812 days	
e	=	·073	±·017
ω_1	=	59°·16	±1°·12
ω_2	=	239°·16	±1°·12
K_1	=	86·03 km.	±1·98 km.
K_2	=	86·04 km.	±1·95 km.
γ	=	+8·80 km.	±1·04 km.
T	=	J.D. 2,423,630·622	
$a_1 \sin i$	=	5,677,400 km.	
$a_2 \sin i$	=	5,678,000 km.	
$m_1 \sin^3 i$	=	1·26 ⊙	
$m_2 \sin^3 i$	=	1·26 ⊙	

The solution improved the agreement and resulted in a lowering of Σpvv for the normal places from 247·4 to 184·9, a matter of twenty-five per cent. The graph accompanying represents the final elements, the full circles representing component I and the broken circles component II.

August, 1925.

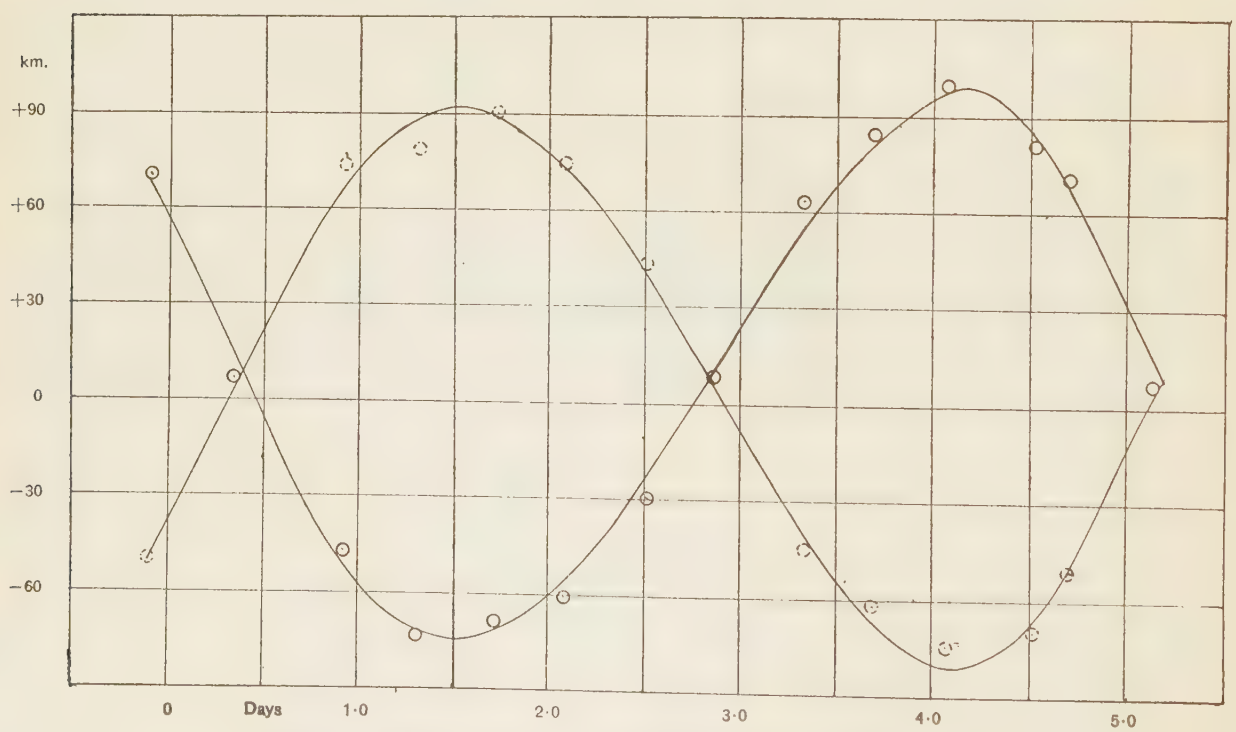

Fig. 3. Velocity Curves of H.R. 7267 Showing Grouped Observations.

H. R. 8257

Abstract.—Thirty-two spectrograms of this double-line F-type star, on twenty-three of which both sets of lines were measured, form the basis of the determination of the elements of the spectroscopic orbit. One spectrum is considerably stronger than the other though the masses differ only in the ratio of 65 to 52. The period is 12·21 days and the eccentricity ·318.

The star H.R. 8257 (1900 $\alpha = 21\text{h}\ 30\text{m}\cdot9$, $\delta = +27^\circ\ 46'$), whose visual magnitude is 6·35 and type F3, was discovered by the writer to be a spectroscopic binary from the first plate taken on October 8, 1923, as two sets of spectral lines were recorded. Six plates were secured that year, eleven in 1924 when the period was found, and fifteen in the present year. Of the total of thirty-two plates there were twenty-three showing the component spectra sufficiently resolved to be measurable so that the determination is based upon nine single line and twenty-three double line plates, or the equivalent of fifty-five plates. They were all made with the single-prism equipment giving a dispersion at Hγ of 29 angstroms per millimetre.

The plates were all measured on the micrometer engine the number of lines measured in each case being given in the table of observations. The spectrum lines of the main component are always stronger than those of the secondary, but the ratio does not appear to remain constant. This variation might repay a fuller study than the writer has given it, but in general it may be stated that when the main component is receding from the earth in its orbit the lines are more nearly equal than when it is approaching. In the former case a ratio of probably 3 to 2 would be a fair estimate of the relative intensities of the two sets of lines whilst in the latter case the difference in intensities is much greater, the main one having two or three times the intensity of the secondary. The lines that are completely free of any vitiating effect of neighbouring lines in spectra of this type made with single-prism dispersion are limited in number but the above estimate of the relative intensities does not seem to be overstating the case.

OBSERVATIONS OF H.R. 8257

Plate Number	Date	Julian Date	Phase	Main Component				Secondary Component			
				Vel.	Lines	Wt.	O-C	Vel.	Lines	Wt.	O-C
9496	1923 Oct. 8	2,423,701·701	3·843	−85·5	10	3	− 2·1	+ 6·5	6	2	− 0·8
9527	" 12	3,705·714	7·856	−44·2	1–19	3	+ 0·2				
9540	" 22	3,715·628	5·560	−81·2	6	2	− 8·7	− 16·6	6	2	−10·8
9565	" 26	3,719·740	9·672	−13·9	13	3	− 3·9				
9593	Nov. 5	3,729·692	7·414	−45·0	1–19	3	−11·5				
9645	Dec. 7	3,761·646	2·788	−83·9	7	2	− 2·5	− 1·2	4	2	− 5·9
10248	1924 July 7	3,974·907	8·429	−42·7	1–19	3	− 8·1				
10332	" 21	3,988·880	10·192	+ 5·1	13	3	+ 1·0	− 99·7	10	3	− 0·1
10594	Sept. 1	4,030·779	3·251	−83·4	11	3	+ 0·1	+ 16·0	5	2	+ 8·2
10625	" 6	4,035·836	8·308	−41·5	1–19	3	− 4·9				
10635	" 8	4,037·808	10·280	+ 6·8	15	3	+ 2·8	−114·3	11	3	−12·0
10726	" 15	4,044·772	5·034	−81·8	10	3	− 4·8	− 5·6	6	2	− 5·2
10780	" 26	4,055·746	3·798	−82·2	11	3	+ 1·2	+ 11·6	5	2	+ 4·0
10811	Oct. 2	4,061·799	9·851	− 5·4	12	3	− 0·1	− 93·3	6	2	− 2·8
10851	" 9	4,068·756	4·598	−81·0	14	3	− 0·5	+ 6·0	7	2	+ 2·6
10911	" 31	4,090·705	2·127	−75·2	11	3	0·0	− 10·3	5	2	− 6·7
10987	Nov. 28	4,118·648	5·650	−68·7	12	3	+ 2·7	− 15·0	5	2	− 8·0
11090	Dec. 23	4,143·564	6·146	−57·4	20	2	+ 9·2				
11613	1925 May 11	4,282·985	11·257	+21·4	18	4	+ 1·4	−117·0	13	3	+ 5·0
11672	" 25	4,296·936	0·788	−33·3	16	3	+ 0·2				
11847	July 6	4,338·932	6·154	−54·9	19	2	+11·5				
11875	" 10	4,342·939	10·161	+ 2·1	14	3	+ 0·9	− 97·0	6	2	+ 2·2
11903	" 18	4,350·829	5·841	−66·0	13	3	+ 3·8				
11984	" 27	4,359·916	2·718	−74·0	13	3	+ 7·2	+ 18·1	2	1	+13·4
12045	Aug. 3	4,366·846	9·648	−12·2	9	3	− 2·2	− 83·7	5	2	+ 1·2
12050	" 3	4,366·963	9·765	−12·6	9	3	− 5·3	− 86·6	5	2	+ 1·0
12120	" 17	4,380·747	11·339	+17·8	10	3	− 2·2	−125·4	8	2	− 2·8
12126	" 17	4,380·918	11·510	+23·3	12	3	+ 3·4	−131·3	7	2	− 8·7
12183	" 29	4,392·657	11·039	+20·3	16	4	+ 3·0	−118·7	9	2	+ 0·7
12186	" 29	4,392·806	11·188	+17·5	13	3	− 1·9	−116·6	11	2	+ 5·4
12203	" 30	4,393·686	12·068	+15·7	16	4	+ 7·0	−111·0	14	3	− 5·0
12256	Sept. 11	2,424,405·791	11·963	+15·5	10	3	+ 4·0	−124·6	5	2	−13·2

The period determined from the three seasons' observations is 12·21 days, and it was not included in the least-squares solution. The observations were grouped according to phase into 20 normal places, 11 representing the main, and 9 the secondary component.

NORMAL PLACES

	Mean Phase		Mean Vel.	Wt.	O-C			Mean Phase		Mean Vel.	Wt.	O-C	
	Prel.	Final			Prel.	Final		Prel.	Final			Prel.	Final
1	3·125	3·627	−83·7	0·9	+ 4·0	0·0	11	1·999	2·501	− 76·9	0·8	+ 6·4	+ 2·8
2	4·500	5·002	−81·4	0·8	− 2·2	−4·0	12	3·125	3·627	+ 11·4	0·6	− 3·5	+ 3·7
3	5·405	5·907	−62·9	1·0	+ 7·1	+6·6	13	4·314	4·816	+ 0·2	0·4	− 5·7	− 1·2
4	7·500	8·002	−43·4	1·2	− 1·8	−1·3	14	5·103	5·605	− 15·8	0·4	−11·6	− 9·2
5	9·193	9·695	−12·9	0·9	− 1·4	−3·7	15	9·204	9·706	− 85·2	0·4	+ 0·9	+ 1·2
6	9·504	10·006	− 1·6	0·6	+ 3·8	+0·6	16	9·504	10·006	− 95·2	0·4	− 1·4	− 0·5
7	9·734	10·236	+ 6·0	0·6	+ 6·9	+3·0	17	9·734	10·236	−107·0	0·6	− 7·2	− 5·8
8	10·751	11·253	+20·2	1·7	+ 4·3	+0·5	18	10·764	11·266	−121·4	1·1	+ 0·7	+ 0·8
9	11·521	12·023	+15·6	0·7	+ 0·8	+5·3	19	11·480	11·982	−116·4	0·5	+ 4·9	− 4·4
10	0·286	0·788	−33·3	0·3	−10·1	+0·2	20	1·988	2·486	− 1·0	0·5	− 9·9	− 3·5

From graphical methods the following preliminary elements were decided upon.

Preliminary Elements

$P = 12{\cdot}21$ days
$e = {\cdot}32$
$\omega_1 = 60°$
$\omega_2 = 240°$
$\gamma = -43{\cdot}48$ km.
$K_1 = 53$ km.
$K_2 = 70$ km.
$T = $ J.D. 2,423,710·570

From these elements there were built up a set of observation equations connecting the residuals with the elements and of the form given in Dominion Observatory Publications, Volume I, page 327. For the sake of homogeneity the following substitutions were made.

$x = \delta\gamma$
$y = \delta K_1$
$z = \delta K_2$
$u = 100 \cdot \delta e$
$v = -100 \cdot \delta\omega$
$w = 60{\cdot}511\ \delta T$

OBSERVATION EQUATIONS FOR H.R. 8257

1.....	1·000x	− ·834y	+ ·000z	+ ·357u	+ ·091v	− ·037w	− 4·0	= 0
2.....	1·000	− ·675	+ ·000	+ ·514	− ·145	− ·148	+ 2·2	
3.....	1·000	− ·500	+ ·000	+ ·411	− ·251	− ·188	− 7·1	
4.....	1·000	+ ·036	+ ·000	− ·123	− ·379	− ·261	+ 1·8	
5.....	1·000	+ ·603	+ ·000	− ·536	− ·328	− ·321	+ 1·4	
6.....	1·000	+ ·719	+ ·000	− ·553	− ·292	− ·325	− 3·8	
7.....	1·000	+ ·804	+ ·000	− ·538	− ·259	− ·322	− 6·9	
8.....	1·000	+1·121	+ ·000	− ·064	+ ·000	− ·170	− 4·3	
9.....	1·000	+1·100	+ ·000	+ ·556	+ ·329	+ ·281	− 0·8	
10.....	1·000	+ ·383	+ ·000	− ·125	+ ·664	+ ·881	+10·1	
11.....	1·000	− ·751	+ ·000	− 212	+ ·366	+ ·206	− 6·4	
12.....	1·000	+ ·000	+ ·834	− ·472	− ·120	+ ·049	+ 3·5	
13.....	1·000	+ ·000	+ ·705	− ·686	+ ·158	+ ·183	+ 5·7	
14.....	1·000	+ ·000	+ ·562	− ·605	+ ·290	+ ·232	+11·6	
15.....	1·000	+ ·000	− ·609	+ ·713	+ ·431	+ ·424	− 0·9	
16.....	1·000	+ ·000	− ·719	+ ·731	+ ·386	+ ·429	+ 1·4	
17.....	1·000	+ ·000	− ·804	+ ·710	+ ·342	+ ·425	+ 7·2	
18.....	1·000	+ ·000	−1·123	+ ·076	− ·004	+ ·221	− 0·7	
19.....	1·000	+ ·000	−1·112	− ·709	− ·408	− ·328	− 4·9	
20.....	1·000	+ ·000	+ ·748	+ ·290	− ·486	− ·276	+ 9·9	

From these there resulted the normal equations:—

14·400x	+1·896y	−1·425z	+ ·013u	− ·456v	− ·259w	−6·630	=	0
	5·744	+ ·000	−1·126	− ·200	− ·410	−2·570		
		3·768	− ·884	− ·281	− ·497	+9·602		
			2·875	+ ·680	+ ·714	+1·092		
				1·220	+1·076	+3·236		
					1·160	+7·795		

which gave corrections to the preliminary elements as follows:—

$\delta\gamma$ = +·31 km.
δK_1 = −1·05 km.
δK_2 = −4·76 km.
δe = −·002
$\delta\omega$ = −13°·21
δT = −·502 days

Hence the final values of the elements with their probable errors are the following:—

FINAL ELEMENTS

P	=	12·21 days	
e	=	·318	±·019
ω_1	=	46°·79	±3°·48
ω_2	=	226°·79	±3°·48
K_1	=	51·95 km.	±1·23 km.
K_2	=	65·24 km.	±1·54 km.
γ	=	−43·17 km.	±0·74 km.
T	=	J.D. 2,423,710·068	±·089 days
$a_1 \sin i$	=	8,269,800 km.	
$a_2 \sin i$	=	10,385,200 km.	
$m_1 \sin^3 i$	=	0·97 ⊙	
$m_2 \sin^3 i$	=	0·77 ⊙	

The solution improved the agreement considerably, resulting in the lowering of Σpvv for the normal places from 440·9 to 163·5. The probable error of a plate for component I, *i.e.* the main spectrum, is ±3·2 km/sec., and for the secondary ±4·7 km/sec.

The graph represents the final elements, the full circles representing the main and the broken the secondary component.

September, 1925.

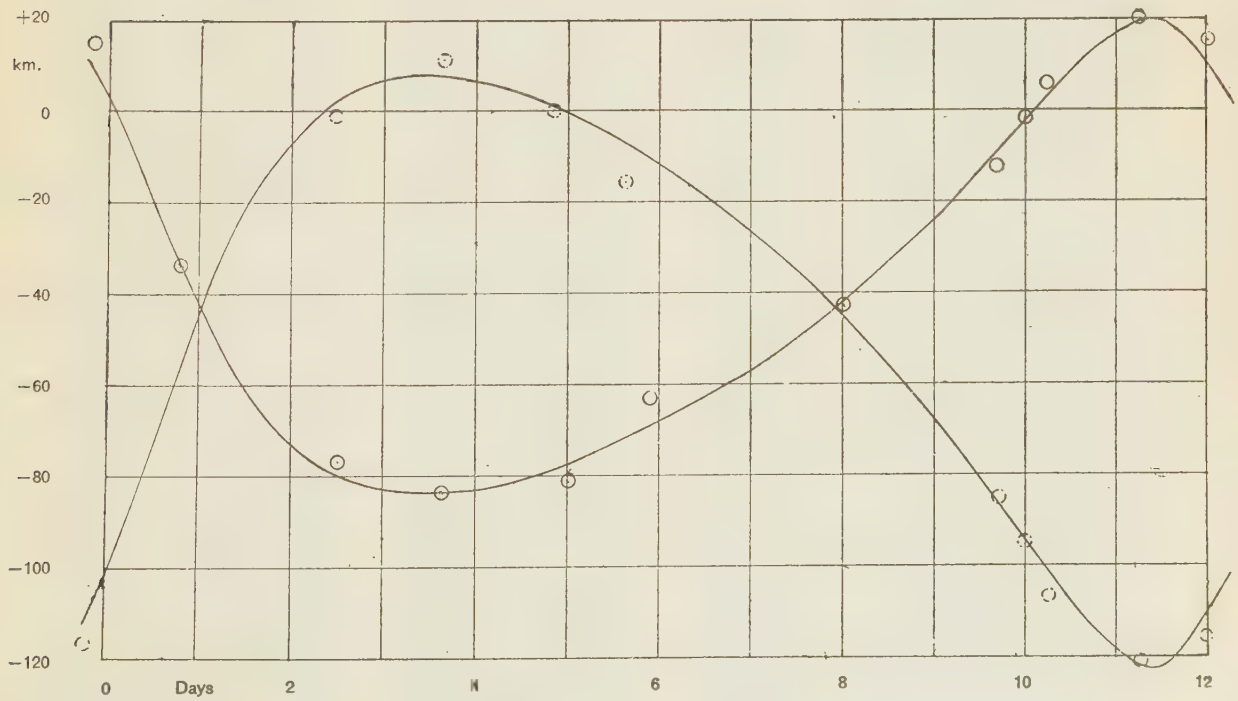

Fig. 4. Radial Velocity Curves of H.R. 8257.

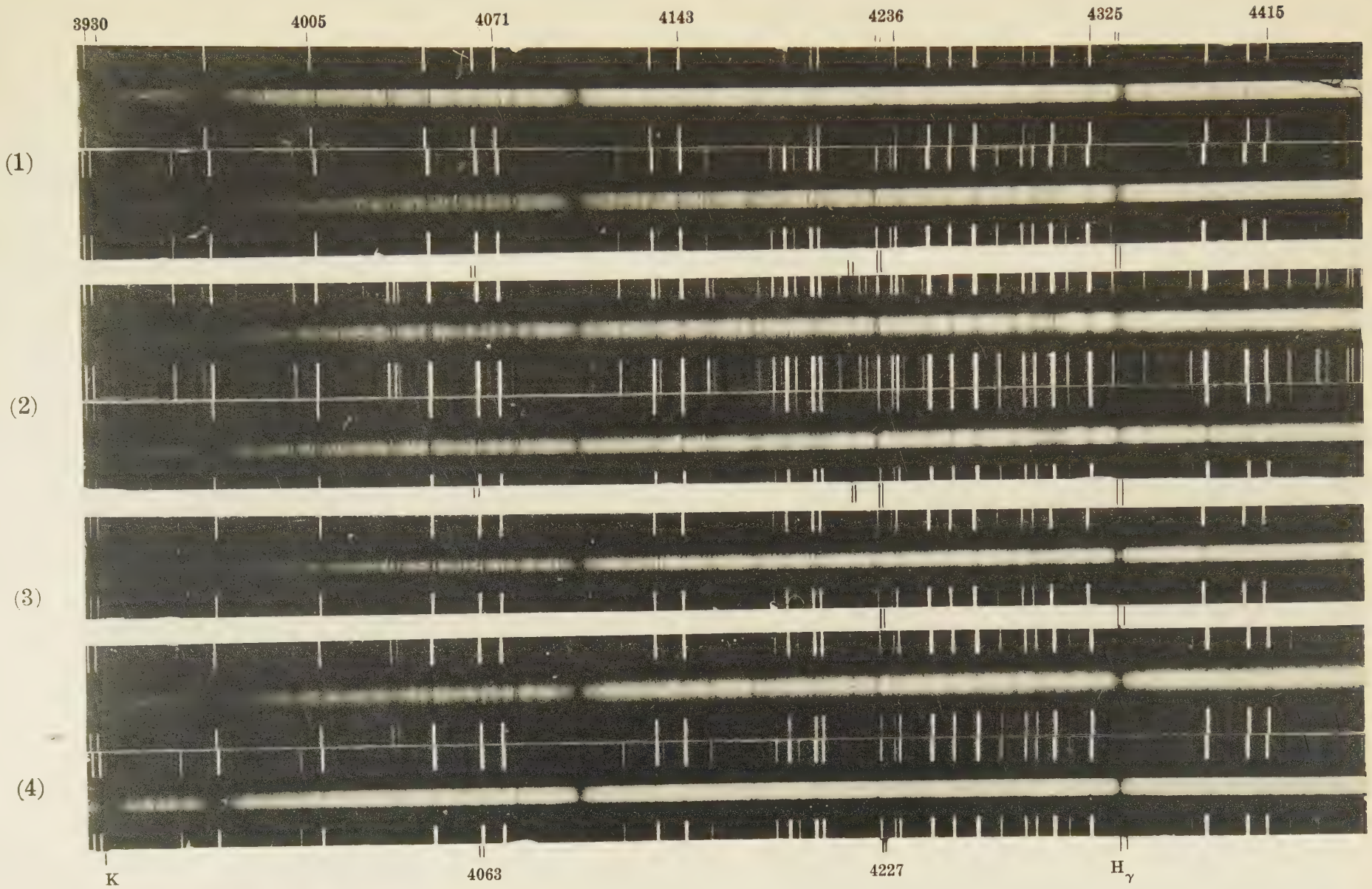

PLATE VI.—Spectra of double line F-type stars. (1) 63 Geminorum. (2) σ_2 Coronae Borealis. (3) HR7267. (4) HR8257.

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THREE SPECTROSCOPIC BINARY ORBITS

By

J. S. Plaskett

ABSTRACTS

21 Cassiopeiae.—The orbit of this eclipsing variable undertaken at the suggestion of its discoverer, Stebbins, is of special interest on account of the opportunity given by its fine-lined spectrum and the practical coincidence of photometric and spectroscopic observations to test the differences in phase obtained by the two methods, previously observed by Schlesinger and the writer in other Algol variables. The paper is in two parts on account of the first part being completed before the photometric data were available. The first part contains the elements determined by 25 spectra well distributed over the velocity curve and corrected by least-squares for K, e, ω and γ. The difference between spectroscopic and photometric minimum is 24 minutes, considerably too large apparently to be chargeable to accidental error. It was, therefore, considered desirable to observe further around minimum and 13 additional plates were obtained about a year later, all within a quarter of a day of minimum. As the final photometric orbit showed negligible eccentricity a second and third solution, assuming circular orbits and with and without the additional plates, were made. These reduced the difference of phase to about 4 minutes, well within the accidental error. The reasons for the change and the probable effect of similar procedure on the earlier observed differences are discussed. The spectra around minimum show a rotation effect which appears to indicate identical values of the periods of rotation and orbital revolution.

Boss 3354.—This double-lined A-type binary discovered in 1919 by the writer was further observed in the summer of 1924. The orbital work followed the usual course resulting in the elements $P = 3 \cdot 28655$ days, $e = \cdot 0408$, T = J.D. $4226 \cdot 669$, $\omega = 211° \cdot 05$, $K_1 = 108 \cdot 34$, $K_2 = 128 \cdot 863$, $\gamma = -0 \cdot 05$. The masses are $m_1 \sin^3 i = 2 \cdot 47 \odot$, $m_2 \sin^3 i = 2 \cdot 08 \odot$ while the projected semi-axis major is 11,880,000 km.

H.D. 191201.—The first plate obtained showed double lines of separation 360 km., and the orbit was determined from 36 plates. The star is of type O9 to B0 and the lines, especially of the secondary, are very difficult to measure indicated by the high probable errors of $\pm 9 \cdot 9$ and $\pm 25 \cdot 2$ km. per sec. Least-squares corrections for all the elements were carried through and a satisfactory orbit obtained. The star is unusual for its high eccentricity of $0 \cdot 26$ and the masses also are large, the minimum masses being $13 \cdot 8$ and $12 \cdot 9$ times the sun. From probable estimates of density and calculated values of surface brightness it seems certain that this star must be at least 5,000 light years distant.

17187—1

THE ORBIT OF 21 CASSIOPEIAE

PART I

The spectroscopic observation of 21 Cassiopeiae, R.A. 0h 39·0m, Dec. +74° 26′, Vis. Mag. 5·59, Spectrum A2, was undertaken at the kind suggestion of Professor Stebbins who had discovered its variation in light by the photo-electric photometer. The nearly simultaneous observation photometrically and spectroscopically, with the fine quality of the spectrum for measurement, offered a good opportunity of testing the coincidence of spectroscopic and photometric phases of which many puzzling discrepancies in the Algol variables have been found.

The spectrum of type A2 is of fine quality for measurement, containing numerous sharp metallic lines, of which about 20 were measured on each plate. Consequently, the measures are reliable as indicated by the low probable error for single-prism plates of ±1·24 km. per second. For the measures of 19 of the 25 plates used in the orbit, the writer is indebted to Mr. S. N. Hill, computer at the observatory, and the accuracy of his measurement is well shown by the low probable error and the close fitting of the observations to the velocity curve. There seems, in the plates obtained for this solution, to be no evidence of any rotational effect near the time of eclipse, and apparently any deviation from simple elliptic motion thereby produced is negligible so far as these first observations are concerned. Dean B. McLaughlin, of the Detroit Observatory, proposed to examine 21 Cassiopeiae with this end in view, but at the time of writing no resuts are at hand.

The first spectrum was obtained on June 29, 1924, and between that date and October 18 inclusive, 25 spectra were obtained of which all but one by the short-focus camera were made with the medium-focus camera giving linear dispersion at Hγ of 29 A per millimetre. These observations arranged in order of final phase are given in the following table, which is self-explanatory. It should, however, be mentioned, owing to the importance of careful timing in comparing photometric and spectroscopic phases, that the average exposure time was about 12 minutes, so that there is little room for uncertainty in assuming the mid-exposure as the true time of the observation. Further, although normally the observing clock may have a correction of two or three minutes, unimportant in most cases, the correction, on each night on which 21 Cassiopeiae was observed, was obtained by computing from the recorded initial hour angle of every observation of the night and averaging. Hence the clock correction and the time of each observation of 21 Cassiopeiae was determined certainly within a minute which, when spread accidentally over 25 observations, would make any uncertainty on this score a matter of a few seconds only. The velocities given were very carefully determined and are in most cases the mean of two, and sometimes of three, individual measures.

TABLE I.—OBSERVATIONS OF 21 CASSIOPEIAE

Plate Number	Julian Date	Final Phase	Velocities		Residuals	
			Obs'd.	Comp.	Prel.	Final
10672	4039·892	0·020	−52·2	−51·41	+0·93	−0·79
10877	4071·760	0·617	− 2·0	+ 0·16	−0·62	−2·16
10602	4031·894	0·956	+36·6	+34·41	+3·36	+2·19
10692	4040·903	1·031	+40·7	+41·36	+0·43	−0·66
10496	4009·961	1·359	+65·8	+66·28	+0·38	−0·48
10519	4018·943	1·408	+70·1	+69·01	+1·93	+1·09
10815	4063·663	1·455	+70·7	+71·44	+0·06	−0·74
10209	3969·951	1·554	+77·9	+75·87	+2·72	+2·03
10277	3978·960	1·628	+76·1	+77·86	−1·14	−1·76
10391	3996·961	1·761	+78·7	+80·14	−1·03	−1·44
10461	4005·968	1·833	+80·4	+80·40	+0·27	0·00
10880	4077·684	2·074	+74·5	+76·31	−2·15	−1·81
10854	4068·851	2·175	+72·0	+72·42	−1·07	−0·42
10507	4010·953	2·351	+66·7	+62·88	+2·45	+3·82
10221	3970·954	2·557	+45·2	+47·81	−4·64	−2·61
10284	3979·947	2·615	+45·9	+42·95	+0·73	+2·95
10831	4064·828	2·620	+40·5	+42·53	−4·46	−2·23
10400	3997·937	2·737	+35·4	+32·06	+0·77	+3·34
10187	3966·959	3·029	+ 2·3	+ 3·71	−4·50	−1·41
10259	3975·960	3·096	− 2·9	− 2·90	−3·11	0·00
10442	4002·981	3·313	−25·5	−23·51	−4·84	−1·99
10531	4020·967	3·431	−33·6	−33·71	−2·43	+0·11
10792	4056·753	3·479	−37·8	−37·54	−2·65	−0·26
10473	4007·971	3·836	−56·6	−58·60	+1·25	+2·00
10450	4003·961	4·293	−60·2	−60·11	+1·19	−0·09

The preliminary period, given by Stebbins from the photometric measures as 4·4672 days, was accepted and, from the velocity curve plotted with this period, the usual method of trial and error determined preliminary elements given in Table II. From these preliminary elements observation equations were formed by Schlesinger's method including as unknowns e, K, γ, and ω, but not P or T, the former being considered as determined by the photometric work and, the latter, owing to the small eccentricity, being indeterminate when corrections for both T and ω are attempted.

From the observation equations the following normal equations were obtained in the usual way:

$$\begin{aligned} 25\cdot000\Gamma + 7\cdot242\kappa + 3\cdot758\pi - 9\cdot901\epsilon &= -16\cdot17 \\ +12\cdot842\kappa - \cdot925\pi - 1\cdot366\epsilon &= + \cdot890 \\ +12\cdot155\pi - 1\cdot971\epsilon &= -24\cdot392 \\ +6\cdot355\epsilon &= +11\cdot311 \end{aligned}$$

Their solutions gave for the unknowns:—

Γ	=	+ ·4287	whence	$\delta\gamma$	=	− ·232
K	=	− ·1374		δK	=	− ·137 ±0·43
π	=	−2·2695		$\delta\omega$	=	+1°·805 ±0°·318
ϵ	=	+1·6506		δe	=	− ·0100 ± ·0057

and the final values of the elements.

TABLE II.—ELEMENTS OF 21 CASSIOPEIAE

Element	Preliminary	Final
P Period	4·4672	4·4672 days
e Eccentricity	0·03	0·0200 ±·0057
ω Longitude of apse	210°	211°·805 ±0°·318
T Time of periastron	3963·930	3963·930
K Semi-amplitude	72·0	71·86 ±0·43 km.
γ Velocity of system	+10·0	+9·77 km.

The sum of the squares of the residuals, all the observations being given equal weight, was reduced by the solution from 151·7 to 81·5, and the probable error of a single plate becomes ±1·24 km. per second. From these elements are readily obtained

$$a \sin i = 4{,}414{,}300 \text{ km.}$$

$$\frac{m_2{}^3 \sin^3 i}{(m_1+m_2)^2} = 0{\cdot}172\odot$$

The times of principal and secondary minima when u equals 90° and 270° respectively, correspond to phases in the orbit from periastron of 2·980 and 0·698 or to Julian times 3966·910 and 3964·628. According to the preliminary value kindly sent by Stebbins the time of principal photometric minimum is 3966·893 days, a difference of ·017 days or 24 minutes. The probable error of the determination of ω is ±0°·318 or translated into time ±·004 days, about 6 minutes, so that the difference appears large to be considered accidental. In order to check whether a different method would change this difference, a new solution, assuming ω fixed and correcting for T, was made, resulting in practically identical values of the time of spectroscopic minimum.

PART II

Shortly after the above spectroscopic orbit was completed and the results sent to Stebbins, he sent to us a final value of the period and preliminary values of the times of principal and secondary minima as obtained by Mr. Huffer. The final period is 4·46718 days instead of 4·4672, while a comparison of spectroscopic and photometric minima is given below:—

	Spectroscopic	Photometric	Diff. Days	Minutes
Primary minimum t_1	2,423,966·910	3,966·8931	+·017	+24
	±·004	±·0006		
Secondary minimum t_2	3,969,095	3,969·1260	−·031	−45
	±·004	±·0024		
Difference t_2-t_1	2·185	2·2329		
Half the period		2·2336		

As the half period differs by less than a thousandth of a day from the interval between primary and secondary minima and as this interval has a low probable error and is a very sensitive method of determining the eccentricity, there seems to be little doubt that the orbit is practically circular and the eccentricity obtained in the above solution arises from the grouping of the errors of observation and their adjustment by least-squares. Consequently, it was decided to make a new solution with eccentricity zero but before doing so to obtain additional plates near principal minimum.

Thirteen additional plates in the interval between ·125 days before and ·252 days after principal photometric minimum were obtained and measured, their dates, phases, observed and computed velocities and residuals along with those of the earlier plates being given in the table of observations, Table III, below. Preliminary circular elements were obtained from the whole series of 38 plates using the corrected period of 2·46718 days and initial phase T_o corresponding to the time when the velocity curve crosses the γ line with increasing velocity or when the bright component is nearest the earth and hence corresponding to secondary minimum. These are given in comparison with the final elements in Table IV below.

TABLE III.—SECOND TABLE OF OBSERVATIONS

Plate Number	Julian Date	Final Phase	Velocities		Residuals		
			Observed	Computed	Preliminary	Final	First Solution
10602	4031·894	0·229	+36·6	+32·61	+3·61	+3·99	+2·19
10692	4040·903	0·304	+40·7	+39·62	+0·65	+1·08	−0·66
10496	4009·961	0·632	+65·8	+65·46	−0·22	+0·34	−0·48
10519	4018·943	0·680	+70·1	+68·38	+1·15	+1·72	+1·09
10815	4063·663	0·728	+70·7	+71·03	−0·91	−0·33	−0·74
10209	3969·951	0·827	+77·9	+75·60	+1·72	+2·30	+2·03
10277	3978·960	0·901	+76·1	+78·18	−2·67	−2·08	−1·76
10391	3996·961	1·034	+78·7	+80·97	−2·84	−2·27	−1·44
10461	4005·968	1·106	+80·4	+81·44	−1·59	−1·04	0·00
10880	4077·684	1·348	+74·5	+77·71	−3·66	−3·21	−1·81
10854	4068·851	1·449	+72·0	+73·79	−2·20	−1·79	−0·42
10507	4010·953	1·624	+66·7	+64·02	+2·39	+2·68	+3·82
10221	3970·954	1·830	+45·2	+48·41	−3·33	−3·21	−2·61
10284	3979·947	1·888	+45·9	+43·38	+2·45	+2·52	+2·95
10831	4064·828	1·893	+40·3	+42·93	−2·70	−2·63	−2·23
10400	3997·937	2·010	+35·4	+32·09	+3·32	+3·31	+3·34
12371	4417·951	2·109	+22·7	+22·45	+0·34	+0·25	
12372	4417·979	2·137	+21·2	+19·74	+1·57	+1·46	
12373	4418·007	2·167	+21·1	+16·70	+4·56	+4·40	
12374	4418·041	2·199	+15·2	+13·46	+1·91	+1·74	
12518	4435·954	2·243	+11·2	+ 9·05	+2·35	+2·15	
12519	4435·983	2·272	+10·6	+ 6·12	+4·69	+4·48	
12443	4427·051	2·274	+ 3·0	+ 5·93	−2·71	−2·93	
12444	4427·064	2·287	+ 0·6	+ 4·62	−3·79	−4·02	
12520	4436·011	2·300	− 1·6	+ 3·32	−4·39	−4·92	
10187	3966·959	2·302	+ 2·3	+ 3·13	−0·59	−0·83	−1·41
10259	3975·960	2·369	− 2·9	− 3·54	+0·92	+0·64	0·00
12474	4431·626	2·382	− 3·7	− 4·82	+1·41	+1·12	
12475	4431·670	2·426	− 9·9	− 9·12	−0·45	−0·78	
12476	4431·701	2·457	−12·2	−12·11	+0·26	−0·09	
12477	4431·728	2·484	−12·3	−14·67	+2·73	+2·37	
10442	4002·981	2·587	−25·5	−24·09	−0·99	−1·41	−1·99
10531	4020·967	2·704	−33·6	−33·92	+0·80	+0·32	+0·11
10792	4056·753	2·752	−37·8	−37·62	+0·32	−0·19	−0·26
10473	4007·971	3·109	−56·6	−57·39	+1·36	+0·79	+2·00
10450	4003·961	3·567	−60·2	−58·18	−1·58	−2·02	−0·09
10672	4039·892	3·760	−52·2	−49·94	−1·93	−2·26	−0·79
10877	4071·760	4·358	− 2·0	− 0·94	−1·19	−1·06	−2·16

From these observations and the preliminary elements simple observation equations for the corrections $\delta\gamma$, δK and δT were formed. Normal equations were obtained from these 38 observation equations in two ways. First—the first sixteen and the last twelve were combined, omitting the ten plates whose phases were between 2·109 and 2·302 days inclusive, those within 0·13 days from the minimum and in which a rotation effect might be present. Second—all the observation equations were combined but the ten above mentioned with possible rotation effect were given weight of one-third the others. The first set corresponds practically to the solution in part I except that the orbit is circular, and the second includes all the observations. If a rotation effect is present the orbit and the phase will probably not be affected as the observations, and hence the residuals from the rotation effect, are symmetrically distributed about the minimum and indeed this seems to be shown by the very small differences between the two solutions.

First set Normal Equations—omitting those within ·13 day of minimum:—

$$\begin{aligned} 28{\cdot}000\delta\gamma + 5{\cdot}435\delta K + 6{\cdot}321\delta T &= -2{\cdot}970 \\ +13{\cdot}048\delta K - 2{\cdot}180\delta T &= -8{\cdot}246 \\ +14{\cdot}949\delta T &= +3{\cdot}660 \end{aligned}$$

Second set Normal Equations—all plates included:—

$$\begin{aligned} 31{\cdot}600\delta\gamma + 5{\cdot}447\delta K + 9{\cdot}905\delta T &= -0{\cdot}430 \\ +13{\cdot}079\delta K - 2{\cdot}169\delta T &= -7{\cdot}688 \\ +18{\cdot}517\delta T &= +6{\cdot}199 \end{aligned}$$

The solution of these two normal equations gave for the corrections:—

	1st Normals		2nd Normals	
$\delta\gamma$ =	−0·030	±0·307 km.	−·026	±0·297
δK =	−0·591	±0·447 km.	−·544	±0·425
δT =	+0·00169	± ·00379 days	+·00221	± ·00355 days

As is obvious from Table III, the residuals of the 10 plates near minimum are affected by the rotation of the bright component and are abnormally high, positive before and negative after minimum. Hence the probable errors of the second set have been determined by using the probable error of a plate of unit weight obtained from the first set and are, as they should be, from the larger number of observations, slightly smaller than those of the first set. There result then the following corrected elements.

TABLE IV

Element	Preliminary	First Normals	Second Normals
P Period	4·46718	4·46718	4·46718
K Semi-amplitude	72·0	71·41 ±0·45 km	71·46 ±0·42
γ Vel. system	+10·0	+9·97 ±0·31 km	+9·97 ±0·30
T Nearest approach primary	3964·655	3964·656 + ·0038 days	3964·657 ± ·00355
Primary minimum	3966·889	3966·890	3966·891
Secondary minimum	3969·122	3969·123	3969·124

The photometric phases of primary and secondary minima are 3966·894 and 3969·127 from the final T given by Huffer 3716·732 which makes the spectroscopic phases as determined from the second set of normals of greater weight, ·003 day or about 4 minutes ahead of the photometric, slightly smaller than the probable error of the spectroscopic determination as compared with the 24 minutes, four times the probable error of the earlier solution. It seems hence practically certain, in this case where the spectra are capable of accurate measurement, that there is no observed difference in the times of spectroscopic and photometric minima, just as there is no known physical cause to produce such a difference. The cause of the difference of phase between the earlier and the two later solutions can reasonably be ascribed to the fact that the least-squares solution simply takes the observations as they stand and changes the elements to make the sum of the squares of the residuals a minimum. The difference of a kilometer or so, well within the range of accidental error, in a few of the observations, would be sufficient to produce such a change in the elements. This is shown by a comparison of the residuals from the earlier and later solutions given in the last two columns of Table III where the average change without regard to sign is 0·84 km. and the average change when signs are taken into account is 0·13 km., and is further shown by the fact that the probable error of a single plate of ±1·24 km. per second in the first general solution is increased only to ±1·40 km. per second when the orbit is assumed circular as required by the photometric work.

The relatively large change produced in the spectroscopic phase by a change in the method of solution furnishes some clue as to the cause of the differences between spectroscopic and photometric phases first observed at Allegheny and later at Victoria. The following list contains the data upon this matter readily available.

Star	Reference	*t* spec.-*t* phot.	P.E. Single Plate
Algol	P.A.O. I, 32	−·070	±1·6
δ Librae	" I, 123	−·078	±4·7
u Herculis	" II, 6	−·016 ±·008	±8·0
U Sagittae	" III, 11	−·022 ±·0116	±8·3
λ Tauri	" III, 23	−·098 ±·011	±7·2
R Can. Maj	" III, 49	−·054 ±·039	±4·8
RZ Cassiopeiae	" III, 137	−·035 ±·080	±7·1
TX Herculis	D.A.O. I, 211	+·040 ±·005	±2·6
RS Vulpeculae	" I, 149	+·128 ±·010	±1·8
TW Draconis	" I, 149	+·019 ±·010	±2·6
Z Vulpeculae	" I, 253	−·014 ±·008	±6·0
TV Cassiopeiae	" II, 144	−·0045 ±·0035	±4·1
21 Cassiopeiae	Full solution	+·017 ±·004	±1·24
21 Cassiopeiae	Circular orbit	−·003 ±·003	±1·40

In this list Algol and λ Tauri are three-body systems with changing orbits so that the values are uncertain, while in RS Vulpeculae the photometric minima were obtained uncertainly several years earlier. When the other differences are compared with those obtained for the fine lined spectrum of 21 Cassiopeiae, repeated at the foot of the table it seems evident, especially when the relative plate errors given in the last column are con-

sidered, that they can be similarly explained and that the observed differences are probably due to the method of solution coupled probably in some cases with errors in the photometric phase or period.

The accompanying velocity curves (Fig. 1) show the agreement of the observations with the curves and the slight differences involved in the two solutions. The second shows unmistakably the presence of a rotation effect[1] near minimum reproduced on twice the scale in the inset curve, the rotationally displaced curve being drawn as smoothly as

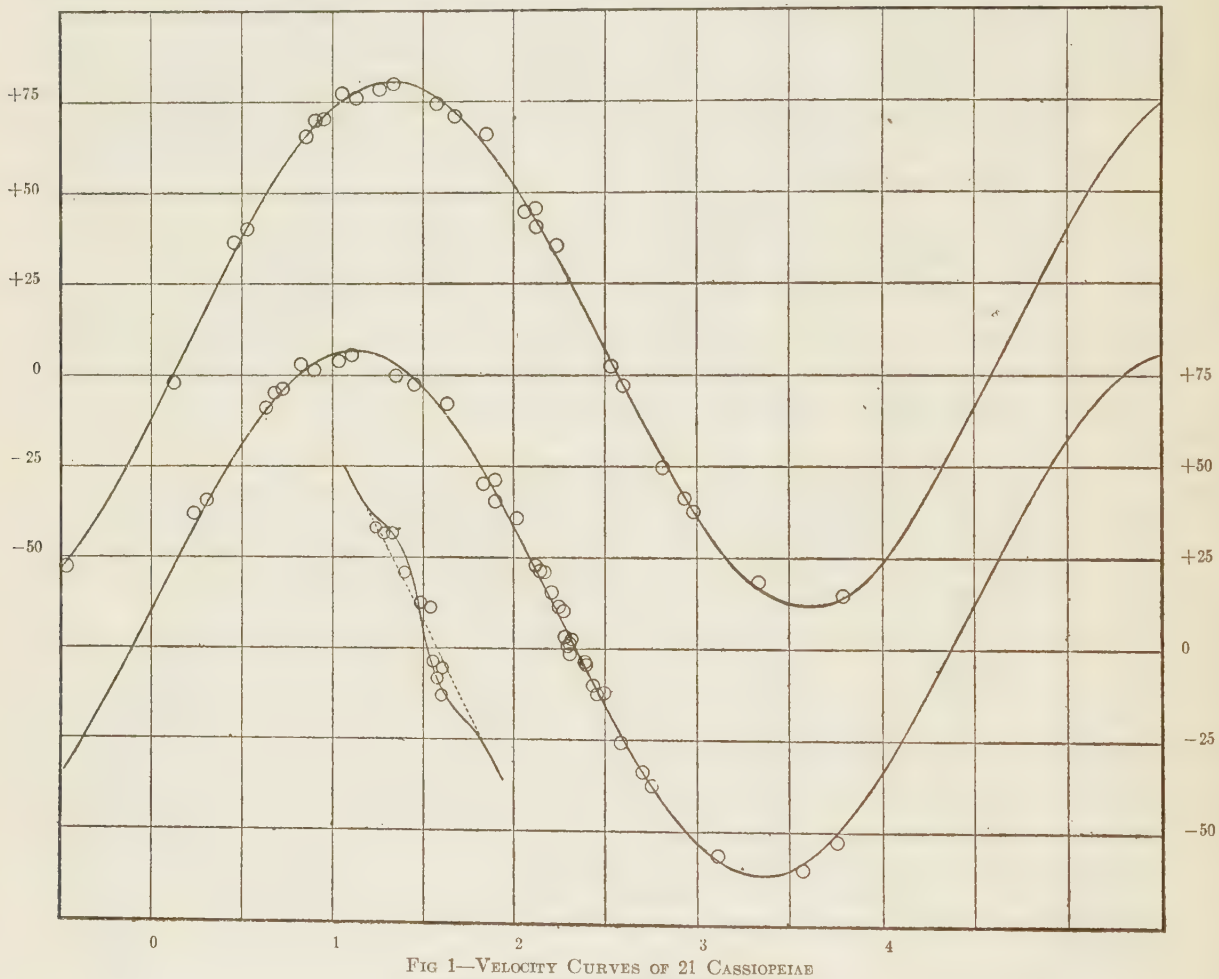

Fig 1—Velocity Curves of 21 Cassiopeiae
Upper Eccentric—Lower Circular Orbit

possible through the observations. Owing to uncertain weather when these were obtained and to the loss of brightness due to eclipse, these plates are not of as good quality as the others but serve to give an approximate value of the rotation effect. The deviation from the sine curve is, at maximum, apparently slightly greater than 3 km. If we take Huffer's values of the relative radii, 0·156 for the bright, 0·076 for the faint star, times the separation of the pair, with an inclination of 87°·4, and assume rotation and revolution periods the same, the effective displacement roughly calculated has a maximum value of about 4 km. The difference between the observed and calculated values, considering the character of

[1] P.A. 32, pp. 21, 225, 558.

the data, is not greater than should be expected and so far as the results go they confirm the probable hypothesis that tidal effects in such a close pair would equalize the periods of rotation and revolution.

THE ORBIT OF BOSS 3354

The star Boss 3354, R.A. $12^h\ 48{\cdot}3^m$, Dec. $+83°\ 58'$, spectral type A0, magnitude 5·81, was one of the stars of the first radial velocity programme undertaken here and on the second plate obtained by the writer on March 25, 1919, the spectrum lines were doubled, indicating its binary character. Four plates were obtained in 1919 and one in 1920, but it was not until last season that further observations were secured. Then it was decided to complete the orbit as between 7 hrs. and 15 hrs. of right ascension there are very few stars in the programme of B's now under investigation. Of the 32 spectra obtained altogether, only 27 were used in the determination of the orbit as the others were in such relation to the crossing points that the lines were not separated and yet were too diffuse to be satisfactorily used.

The spectrum is of type A0 with fairly good hydrogen lines frequently well measurable and a number of sharp metallic lines of which 4481 Mg and 3933 Ca are the best. The number of lines measured varied from 6 to 10 and for a double-lined spectrum the measures seemed fairly reliable and certain so that the relatively high probable error per plate of ±4·3 km. per second was disappointingly large. Although there is not much difference in the intensity of the component lines it was generally possible to distinguish between primary and secondary spectrum.

In the table of observations below are given the serial number, the Greenwich date and the Julian date of the observations with the measured velocities of the primary and secondary stars. The phase and the residuals, observed minus computed, from the final corrected orbit are given in the fourth and the seventh and eighth columns.

TABLE V—OBSERVATIONS OF BOSS 3354

Plate Number	Date	Julian Date	Phase	Velocities		Residuals	
				Primary	Secondary	Primary	Secondary
1526	1919 Mar. 8	2,412,026·907	2·227	+ 0·1	.....	+ 5·6	− 6·3
1698	Mar. 25	043·813	2·700	− 88·8	+106·2	+ 0·9	− 0·3
1734	April 1	050·812	3·126	−104·8	+112·8	+ 5·0	−17·5
1795	April 13	062·782	1·949	+ 44·8	− 56·2	− 2·2	− 0·2
11330	1925 Mar. 18	2,424,227·896	1·227	+107·9	−120·0	+ 5·5	+ 1·9
11348	Mar. 23	232·985	3·029	−108·2	+130·8	+ 3·9	− 2·5
11363	Mar. 26	235·925	2·683	− 78·6	+106·7	+ 8·9	+ 2·8
11376	Mar. 30	239·942	0·126	− 78·0	+100·8	+ 1·1	+ 7·0
11394	April 5	245·834	2·734	−103·2	+115·7	− 9·2	+10·8
11406	April 6	246·907	0·519	+ 8·8	.....	+ 9·0	+ 8·7
11436	April 8	248·795	2·424	− 48·1	+ 60·7	− 3·8	+ 8·1
11449	April 9	249·812	0·137	− 76·9	+ 89·8	+ 0·4	− 1·9
11467	April 10	250·940	1·265	+108·9	−120·3	+ 5·2	+ 3·1
11476	April 13	253·794	0·833	+ 66·6	− 72·1	+ 5·2	+ 0·9
11507	April 17	257·873	1·625	+ 91·6	−110·3	+ 0·9	− 2·2

TABLE V.—OBSERVATIONS OF BOSS 3354—Concluded.

Plate Number	Date	Julian Date	Phase	Velocities		Residuals	
				Primary	Secondary	Primary	Secondary
11516	April 20	260·861	1·327	+106·3	−131·9	+ 1·8	− 7·5
11535	April 23	263·675	0·854	+ 59·7	− 65·9	− 5·1	+11·2
11540	April 23	263·809	0·988	+ 81·2	− 99·0	− 1·1	− 1·0
11546	April 23	263·958	1·137	+ 96·5	−115·5	− 1·1	+ 0·6
11552	April 24	264·847	2·026	+ 40·0	− 46·2	+ 6·7	− 6·4
11566	April 27	267·706	1·598	+106·2	−104·7	+12·8	+ 6·4
11575	April 27	267·944	1·836	+ 53·2	− 84·4	−10·3	− 8·7
11716	June 15	316·724	1·318	+ 96·6	−125·2	− 7·8	− 0·8
11730	June 18	319·800	1·108	+ 90·4	−111·6	− 5·1	+ 2·0
11752	June 21	322·826	0·847	+ 67·4	− 83·2	+ 3·8	− 7·5
11774	June 25	326·818	1·553	+ 86·2	−121·3	−10·5	− 6·2
11837	July 6	2,424,337·783	2·658	− 82·6	+101·7	+ 1·4	+ 1·9

From these observations the period was relatively easily obtained and so adjusted by the fitting of the four early observations that it was considered as definitely determined at 3·28655 days and the period was not included in the least-squares solution. By the usual method of trial and error from the velocity curve plotted with this period the preliminary elements given in Table VII below were obtained. The 27 observations were then grouped into twelve normal places for each component, an ephemeris from the preliminary elements computed and 24 observation equations, formed by Schlesinger's method in the usual way, are given in Table VI below. As the eccentricity is small and both ω and T cannot be accurately determined, the latter was considered fixed and correction made for ω. The last column of this table contains the final residuals computed from the final elements so that preliminary and final residuals can be directly compared.

TABLE VI—OBSERVATION EQUATIONS FOR BOSS 3354

No.	Wt.	r	K_1	K_2	π	ϵ	δV	Final Residual
1	2	1·000	−·695	0	− ·719	−·183	− 2·05	+0·78
2	1	1·000	+·032	0	− ·999	−·807	+ 6·42	+9·00
3	3	1·000	+·619	0	− ·785	−·700	− 0·64	+2·83
4	1	1·000	+·804	0	− ·594	−·487	− 3·87	−1·08
5	2	1·000	+·925	0	− ·380	−·268	− 4·55	−2·40
6	4	1·000	+·995	0	− ·103	−·053	− 0·53	+1·08
7	3	1·000	+·907	0	+ ·421	+·033	− 1·35	+1·05
8	3	1·000	+·511	0	+ ·860	−·372	− 7·66	−2·97
9	1	1·000	+·019	0	+1·000	−·765	+ 1·10	+4·31
10	1	1·000	−·339	0	+ ·941	−·834	−10·78	−3·79
11	4	1·000	−·762	0	+ ·647	−·553	− 8·76	+0·57
12	2	1·000	−·992	0	− ·123	+·044	+ 0·68	+4·48
13	2	1·000	0	+·695	+ ·719	+·183	+10·22	+2·44
14	1	1·000	0	−·032	+ ·999	+·807	+14·53	+8·68
15	3	1·000	0	−·619	+ ·785	+·700	+ 5·97	+0·39
16	1	1·000	0	−·804	+ ·594	+·487	+ 0·33	−1·02
17	2	1·000	0	−·925	+ ·380	+·268	+ 3·78	+0·47
18	4	1·000	0	−·995	+ ·103	+·053	+ 1·72	−0·80
19	3	1·000	0	−·907	− ·421	−·033	+ 3·06	−0·60
20	3	1·000	0	−·511	− ·860	+·372	+ 3·33	−3·94
21	1	1·000	0	−·019	−1·000	+·765	+ 4·70	−7·63
22	1	1·000	0	+·339	− ·941	+·834	+20·06	+8·12
23	4	1·000	0	+·762	− ·647	+·553	+14·12	+2·02
24	2	1·000	0	+·992	+ ·123	−·044	− 0·46	−10·08

From these observation equations the following normal equations were obtained:—

$$\begin{aligned}
54{\cdot}000\Gamma + 6{\cdot}030K_1 - 6{\cdot}030K_2 + {\cdot}000\pi + {\cdot}000\epsilon &= -102{\cdot}288\\
+16{\cdot}080K_1 + {\cdot}000K_2 - 1{\cdot}647\pi - {\cdot}644\epsilon &= +13{\cdot}875\\
+16{\cdot}080K_2 - 1{\cdot}647\pi - {\cdot}644\epsilon &= +73{\cdot}806\\
+21{\cdot}808\pi - 1{\cdot}350\epsilon &= -57{\cdot}945\\
+11{\cdot}004\epsilon &= +25{\cdot}508
\end{aligned}$$

The solution of these normals gave the following corrections:—

$$\begin{aligned}
\epsilon &= +2{\cdot}363 \quad \text{whence} \quad \delta e = -{\cdot}0092 \pm{\cdot}005\\
\pi &= -2{\cdot}119 \qquad\qquad \delta\omega = +{\cdot}0183 = +1^\circ{\cdot}05 \pm 0^\circ{\cdot}44\\
K_1 &= +3{\cdot}863 \qquad\qquad \delta K_2 = +3{\cdot}863 \pm 1{\cdot}07\\
K_2 &= +1{\cdot}345 \qquad\qquad \delta K_1 = +1{\cdot}345 \pm 1{\cdot}05\\
\Gamma &= -1{\cdot}613 \qquad\qquad \delta\gamma = -1{\cdot}68
\end{aligned}$$

and hence the final elements, Table VII.

TABLE VII.—ELEMENTS OF BOSS 3354

Element	Preliminary	Final
P Period	3·28655	3·28655 days
e Eccentricity	0·05	0·0408 ±·005
ω Longitude of node	210°	211°·05 ±0°·44
T Time of periastron	2,424,226·669	2,424,226·669 J.D.
K_1 Semi-amplitude primary	107	108·34 ±1·05 km.
K_2 Semi-amplitude secondary	125	128·86 ±1·07 km.
γ Velocity of system	+1·63	−0·05 km.
$a_1 \sin i$ ⎫ Projected semi-axis major	.....	5,426,000 km.
$a_2 \sin i$ ⎭	.....	6,454,000 km.
$m_1 \sin^3 i$ ⎫ Masses	.....	2·47⊙
$m_2 \sin^3 i$ ⎭	.....	2·08⊙

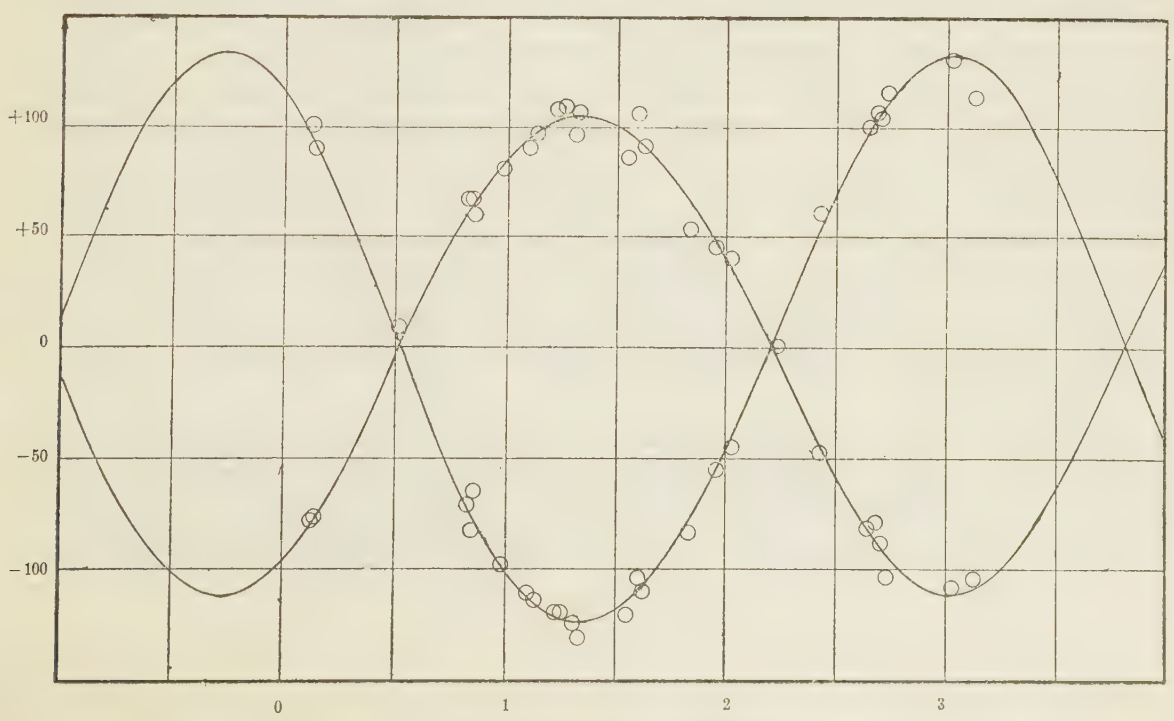

Fig 2—Velocity Curves of Boss 3354

The sum of the squares of the residuals was reduced from 1457 to 711, while the probable error of a single plate became ±4·3 km. per second for the primary and ±4·4 km. per second for the secondary. The accompanying velocity curve (Fig. 2) has the individual velocities indicated by circles.

THE SPECTROSCOPIC BINARY H.D. 191201

The star H.D. 191201, R.A. $20^h\ 03\cdot6^m$, Dec. +35° 26′ (1900), visual magnitude 7·12, spectral type by H.D. catalogue B0, is one of the stars in the B-type programme under investigation here by Mr. J. A. Pearce and the writer. It is one of those allotted to me in the division of the stars between the two observers and on the first plate, obtained on September 18, 1924, the spectrum showed double lines with a relative separation of 360 km. Owing to the interest and value of double-lined spectra for obtaining values of mass and estimates of absolute magnitude and parallax it was decided to investigate the orbit. Spectra of this object were obtained as frequently as possible until December 24, after which it was too near the sun to observe. As the spectra were difficult and the behaviour puzzling, observations were carried on after it had passed conjunction beginning on March 26, and continued until October 1, 1925. Altogether 48 spectra were obtained, of which 40 were measured and 36 used in the orbital work.

Although the writer has measured the spectra and determined the orbits of a considerable number of B and O-type double-lined binaries, in none of them were the measures so difficult and uncertain as in H.D. 191201. This is due to two reasons. First, the lines, even of the primary, are diffuse and weak, while those of the second component have only about half the intensity of the primary, and unless there is a relative separation of nearly 200 km., the pair are blended with resultant uncertainty of position of the maxima of intensity, especially in the case of the secondary. Second, the relatively high eccentricity 0·26 of the orbit with ω nearly zero, makes the proportion of the time when the relative separation of the double lines reaches 200 km. only about half the period. Hence, in a considerable number of the plates, the lines appeared broad, diffuse, weak and unsymmetrical and, especially in the early stages, were measured as single lines. It was only after the period, and hence the position of these spectra on the curve, were approximately known that it was seen these unsymmetrical lines might be considered as the blend of a strong primary and a weak secondary. Considering these spectra as double the plates were remeasured, and while the positions of the primary component were fairly well determined, probable error of single plate ±9·9 km. per second, the uncertainty of the positions of the secondary, even with the most careful measurement, is clearly shown by the high probable error per plate, determined from all the plates measured, of ±25·2 km. per second.

The number of lines measured in the spectra varied from 3 to 24, with an average of about 8 lines. The type of spectrum given as B0 in the Henry Draper Catalogue is in reality somewhat "earlier" as, especially in the single-lined spectra, enhanced helium is conspicuous and its ratios to 4471 and Hγ and the ratios of 4088 to 4097 make the type

between O9 and B0. In the single-lined plate of October 12, 1924, in which 24 star lines were measured, the lines measured include Hβ, Hγ, Hδ: He 4922, 4713, 4472, 4388, 4143, 4026; He+ 4686, 4542, 4339, 4200; Si 4574, 4567, 4552, 4116, 4088; N+ 4097; O+ 4651, 4642, 4076; C+ 4267; S? 4254; Ca+ 3967, 3933. As in similar high temperature stars the lines of ionized calcium H and K are of an entirely different character, are sharp and do not share in the displacements of the other lines.

Of the 48 spectra obtained, 8 were of such poor quality, due to faulty exposure or to blend effects, as to be unsuitable for measurement. Of the 40 spectra measured only 36 were used, the other 4 being so near the crossing points that the blended lines could not be resolved and yet too far away to be safely employed as single-lined spectra. The 36 spectra employed in the orbit are given in the table of observations, Table VIII, below, which contains the Greenwich and Julian dates and the final phases of the observations. The observed velocities are in many cases the means of two independent measures of the spectra while the residuals are obtained from an ephemeris computed from the final elements. The velocities from H and K of calcium are given in the last column. The mean calcium velocity is $-13\cdot3 \pm 0\cdot7$ km. per second while the probable error of a measure is $\pm 3\cdot5$ km. per second. The component of the solar motion in the direction of this star is 18·0 km. per second and the residual velocity $+4\cdot7$ km. per second of the calcium cloud is the same as the average for the eight other O-type stars within a degree of this region previously investigated by the writer.[1]

TABLE VIII.—OBSERVATIONS OF H.D. 192101

Plate Number	Date G.M.T.	Julian Date	Final Phase	Observed Velocities		Residuals O-C		Calcium Velocity
				Primary	Secondary	Primary	Secondary	
		2,424						
11556	1925 April 24	264·983	0·018	+189·4	−166·3	− 3·5	+52·0	−15·0
10904	1924 Oct. 22	081·637	0·025	+192·7	−206·6	− 0·1	+11·6	
11380	1925 Mar. 30	240·042	0·080	+196·8	−165·0	+ 4·9	+52·3	−20·8
12259	Sept. 13	406·806	0·159	+176·6	−185·8	−12·5	+28·5	
11897	July 17	348·872	0·564	+145·6	−127·2	− 6·5	+47·4	−10·0
11442	April 8	249·024	0·727	+141·4	−105·6	+11·3	+45·3	−13·5
12272	Sept. 14	407·739	1·092	+121·3	− 85·3	+34·7	+ 8·2	
10922	1924 Nov. 9	099·622	1·342	+ 8·0	.....	−33·3	.....	− 9·1
12407	1925 Oct. 1	424·815	1·499	− 4·8	.....	−25·6		
10954	1924 Nov. 26	116·568	1·619	+ 6·9	.....	− 0·4	.....	−13·6
11062	Dec. 21	141·580	1·629	+ 14·0	.....	+ 8·9	.....	−12·4
11457	1925 April 9	250·005	1·708	− 2·2	.....	+ 1·7		
10916	1924 Nov. 2	092·631	2·685	− 99·2	+ 62·2	−15·7	−16·2	− 5·6
12207	1925 Aug. 31	393·768	3·789	−107·4	+102·0	+11·5	−14·3	−11·6
10930	1924 Nov. 20	110·622	4·008	−133·3	+100·7	−12·6	−17·6	
10878	Oct. 18	077·603	4·326	−113·5	+130·2	+ 7·0	+12·2	−15·7
11011	Dec. 7	127·610	4·328	−118·4	+156·0	+ 2·1	+38·0	−12·5
11367	1925 Mar. 26	236·042	4·414	−120·9	+189·3	− 1·1	+71·9	
12237	Sept. 9	402·804	4·491	−141·7	+137·5	−22·6	+20·9	
10992	1924 Nov. 29	119·560	4·612	−110·2	+140·7	+ 7·3	+25·9	−11·7
11113	Dec. 24	144·580	4·629	−100·5	+134·1	+16·7	+19·5	−27·2
11732	1925 June 18	319·894	4·923	− 89·6	+126·0	+21·5	+18·1	−21·3

[1] Pub. D.A.O., II, p. 337.

TABLE VIII.—OBSERVATIONS OF H.D. 192101—Concluded.

Plate Number	Date G.M.T.	Julian Date	Final Phase	Observed Velocities		Residuals O-C		Calcium Velocity
				Primary	Secondary	Primary	Secondary	
10932	1924 Nov. 21	111·564	4·950	−102·6	+108·6	+ 7·7	+ 1·4	− 2·1
11994	1925 July 30	361·867	5·225	− 94·6	+130·1	+ 6·9	+32·5	−13·2
10881	1924 Oct. 19	078·617	5·340	−113·2	+179·3	−16·3	+86·6	−12·3
12244	1925 Sept. 10	403·733	5·420	− 95·2	+140·3	− 1·9	+51·4	
10754	1924 Sept. 24	053·781	5·507	− 99·3	+ 90·7	−10·1	+ 6·2	−10·5
11482	1925 April 13	253·981	5·684	− 99·4	+131·8	−19·6	+57·4	
11934	July 23	354·876	6·568	+ 9·5	.....	+17·2	.....	−20·9
10871	1924 Oct. 12	071·670	6·727	− 3·0	.....	−13·4	.....	− 9·5
11033	Dec. 18	138·594	6·977	+ 22·5	.....	−19·5		
11547	1925 April 23	263·982	7·351	+105·2	−128·3	+10·1	−15·0	−17·4
10738	1924 Sept. 18	047·715	7·775	+163·8	−200·5	+ 9·3	−23·3	− 8·7
11757	1925 June 21	322·931	7·960	+186·8	−163·0	+11·9	+36·0	−12·5
11047	1924 Dec. 19	139·610	7·993	+159·9	−140·7	−18·4	+61·8	− 9·9
10823	Oct. 5	064·661	8·052	+179·4	−212·9	− 3·1	− 5·7	−14·6

Considerable difficulty was experienced in obtaining the period of this star, probably mainly due to the shape of the velocity curve, to the large proportion of the plates where the lines appeared single and of course also to the difficult and uncertain measures. Periods of 8·33 and 8·34 days appeared to fit the observations about equally well with a slight preference for 8·33, and as the whole interval covered was only 43 periods, it was obvious that a correction for the period would be required as well as to the other elements. From the velocity curves plotted with a period of 8·33 days preliminary elements were obtained by the usual graphical method, which are given in Table X below.

As a correction to the period was to be included it was impossible to combine generally the observations into normal places. However, where they were grouped closely together in the flat parts of the curve, and where the intervals between them were small, three groups composed of three, two and two plates, plate numbers 10930, 10878, 11011; 10992, 11113; 10881, 10754 respectively, were combined into observation equations 15, 17, 22, thus reducing the number of observation equations to 32.

Owing to the high residuals in many plates it was necessary to weight the observations carefully, else an abnormally high residual, if given undue weight, would too greatly influence the solution. The weights of the individual plates were then based jointly on the number of lines measured, on their interagreement, and on the apparent quality as determined by eyepiece estimates. They were finally limited to three weights, $\frac{1}{2}$, $\frac{2}{3}$ and 1, while the three groups were given the combined weights of their individual plates. The weights of the measures of the second component, on account of their difficulty and uncertainty, were given only half the weights of the primary and hence were $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$.

While it was felt that it would be desirable to use both primary and secondary measures in the solution, the uncertainty of the secondary was so high with the further effect of appearing to have a γ about 20 km. more positive than the primary, that it

appeared desirable to restrict the solution to the primary. However, for the interest of the matter and as the work would not be greatly increased, a set of 24 observation equations was also formed for the secondary in addition to the 32 for the primary, the 8 omitted being near the crossing points where, owing to the weakness of the secondary, it was considered preferable to exclude them. It may be stated at once that the least squares solution of the whole set resulted in values of the elements that gave poorer agreement for the primary than the assumed preliminary values and hence the original opinion in regard to omitting the secondary was confirmed. The 32 observation equations for the primary introducing corrections for γ, K, e, ω, T and P were formed by Schlesinger's method and are given in Table IX. The weights assigned are given in the second column and the final residuals in the last column for comparison with the preliminary residuals in the second last column. The computed values of m, the last unknown, were divided by 100 to make them homogeneous with the others.

TABLE IX.—OBSERVATION EQUATIONS OF H.D. 191201

No.	Weight	Γ	κ	π	ϵ	τ	m	v	Final Residual
1	1·0	1·000	+1·000	−·002	+·000	−·002	− ·001	−1·300	− 3·46
2	0·67	1·000	+ ·994	+·106	+·021	+·105	+ ·236	−3·71	− 0·10
3	0·67	1·000	+ ·986	+·167	+·042	+·165	+ ·332	+5·01	+ 4·91
4	1·0	1·000	+ ·932	+·362	+·160	+·347	+1·272	− 6·76	−12·51
5	1·0	1·000	+ ·692	+·722	+·540	+·619	+1·911	− 0·08	− 6·51
6	1·0	1·000	+ ·601	+·799	+·652	+·660	+1·381	+10·01	+11·34
7	1·0	1·000	+ ·216	+·976	+·888	+·678	+2·483	+40·40	+34·71
8	0·67	1·000	+ ·137	+·990	+·899	+·658	+ ·393	−50·52	−33·26
9	1·0	1·000	− ·091	+·996	+·867	+·594	+ ·455	−15·84	− 0·39
10	0·67	1·000	− ·107	+·994	+·861	+·588	+ ·639	− 6·14	+ 8·86
11	0·67	1·000	− ·118	+·993	+·857	+·582	+2·240	−23·21	−25·65
12	1·0	1·000	− ·205	+·979	+·817	+·551	+1·161	− 7·06	+ 1·72
13	1·0	1·000	− ·693	+·721	+·390	+·315	+ ·166	−27·46	−15·68
14	1·0	1·000	− ·985	+·171	+·012	+·065	+ ·230	+10·29	+11·50
15	3·0	1·000	− ·998	+·054	−·002	+·020	+ ·013	− 1·94	− 1·23
16	0·5	1·000	− ·996	−·088	+·012	−·033	− ·064	− 1·51	− 1·06
17	2·0	1·000	− ·987	−·161	+·032	−·062	− ·057	+12·54	+11·96
18	1·0	1·000	− ·986	−·165	+·033	−·064	− ·232	−23·87	−22·62
19	1·0	1·000	− ·949	−·314	+·100	−·124	− ·089	+ 9·47	+ 7·74
20	1·0	1·000	− ·936	−·352	+·122	−·141	− ·395	+20·38	+21·46
21	1·0	1·000	− ·864	−·503	+·236	−·212	− ·682	+ 4·10	+ 6·86
22	1·67	1·000	− ·851	−·524	+·256	−·223	− ·059	− 9·53	−12·98
23	1·0	1·000	− ·799	−·601	+·330	−·264	− ·960	− 6·69	− 1·86
24	1·0	1·000	− ·731	−·683	+·422	−·314	− ·672	−21·66	−19·62
25	1·0	1·000	− ·192	−·981	+·870	−·606	−1·909	+ 2·64	+17·17
26	0·67	1·000	− ·181	−·983	+·874	−·614	− ·195	−11·58	−13·37
27	0·67	1·000	+ ·054	−·998	+·909	−·694	− ·685	−23·04	−19·47
28	1·0	1·000	+ ·459	−·888	+·723	−·736	−1·651	− 3·83	+10·15
29	1·0	1·000	+ ·734	−·679	+·412	−·625	− ·049	+11·58	+ 9·29
30	0·67	1·000	+ ·910	−·414	+·139	−·404	− ·403	−20·00	−18·38
31	1·0	1·000	+ ·921	−·390	+·122	−·383	− ·095	− 2·15	− 3·13
32	1·0	1·000	+ ·939	−·344	+·090	−·339	− ·959	+ 2·38	+11·93

From these observation equations the following normal equations were formed in the usual way.

$$\begin{aligned}
32{\cdot}273\Gamma - 6{\cdot}056\kappa - 0{\cdot}707\pi + 11{\cdot}224\epsilon - 0{\cdot}187\tau + 2{\cdot}793m &= -88{\cdot}016\\
+19{\cdot}821 + 2{\cdot}271 - 0{\cdot}195 + 0{\cdot}782 + 4{\cdot}506 &= +21{\cdot}103\\
+12{\cdot}359 + 1{\cdot}510 + 7{\cdot}991 + 15{\cdot}314 &= -11{\cdot}320\\
+ 7{\cdot}549 + 0{\cdot}963 + 3{\cdot}196 &= -62{\cdot}313\\
+5{\cdot}458 + 10{\cdot}456 &= - 0{\cdot}625\\
+28{\cdot}453 &= +69{\cdot}490
\end{aligned}$$

The solution of these normal equations resulted in the values of the unknowns and the corresponding value of the corrections below.

Γ	=	− ·8714	whence	$\delta\gamma$	=	−4·898 km.
κ	=	− ·027		δK	=	− ·027 km.
π	=	−15·078		$\delta\omega$	=	+5°·50
ϵ	=	− 8·755		δe	=	+ ·0238
τ	=	+ 4·044		$\delta\Gamma$	=	+ ·0203 days
m	=	+10·145		$\delta\mu$	=	− ·0003845

These corrections give for the final elements with their probable errors the values of Table X.

TABLE X.—ELEMENTS OF H.D. 191201

Element	Preliminary	Final
e Eccentricity	0·24	0·2638 ±·0154
ω Longitude of apse	355°	0°·50 ±4°·83
K_1 Semi amplitude primary	157 km.	156·97 ±2·97 km.
K_2 Semi amplitude secondary	165 km.	168·5 ±7·7 km.
γ Velocity of system	−0·54 km.	−5·44 km.
To Time of periastron	J.D. 4039·92	J.D. 4039·940 ±·108
P Period	8·33 days	8·33425 ±·0016 days
$a_1 \sin i$ Semi axis major primary		17,351,000 km.
$a_2 \sin i$ Semi axis major secondary		18,626,000 km.
$m_1 \sin^3 i$ Mass primary		13·85⊙
$m_1 \sin^3 i$ Mass secondary		12·90⊙

The corrections for K_2 were obtained by accepting the elements obtained from the primary solution and obtaining by least-squares the most probable correction for K_2. As will be seen below, the probable error of a single average plate of K_2, ±25·2 km., is very high, nearly three times that of K_1. If the γ for K_2 were assumed 23 km. more positive than for K_1, a quite impossible condition, the probable error per plate is reduced to ±18·6 km. It is obvious then that the measures of the secondary have not only a very high accidental error, but they are systematically affected also, the lines displaced redward on the plates on the average over 20 km. No explanation, except the difficulty of deter-

mining the intensity maximum in such faint diffuse lines frequently blended with the primary, can be advanced for this curious systematic displacement. The velocity curves with the separate observations plotted as circles are shown in Fig. 3.

The solution reduced Σpvv from 8013 to 6607 and gave the probable error of an average plate of the primary as $\pm 9 \cdot 9$ km. per second and of the secondary as $\pm 25 \cdot 2$ as stated above. These probable errors are not unreasonably high when the difficulty of the spectra are taken into account and, as the amplitude is large, the elements may be considered as fairly reliable. Probably the values of the mass functions are not in error more than five per cent and it will be of interest, as in the previous B- and O-type binaries, to compute the probable absolute magnitude and parallax.

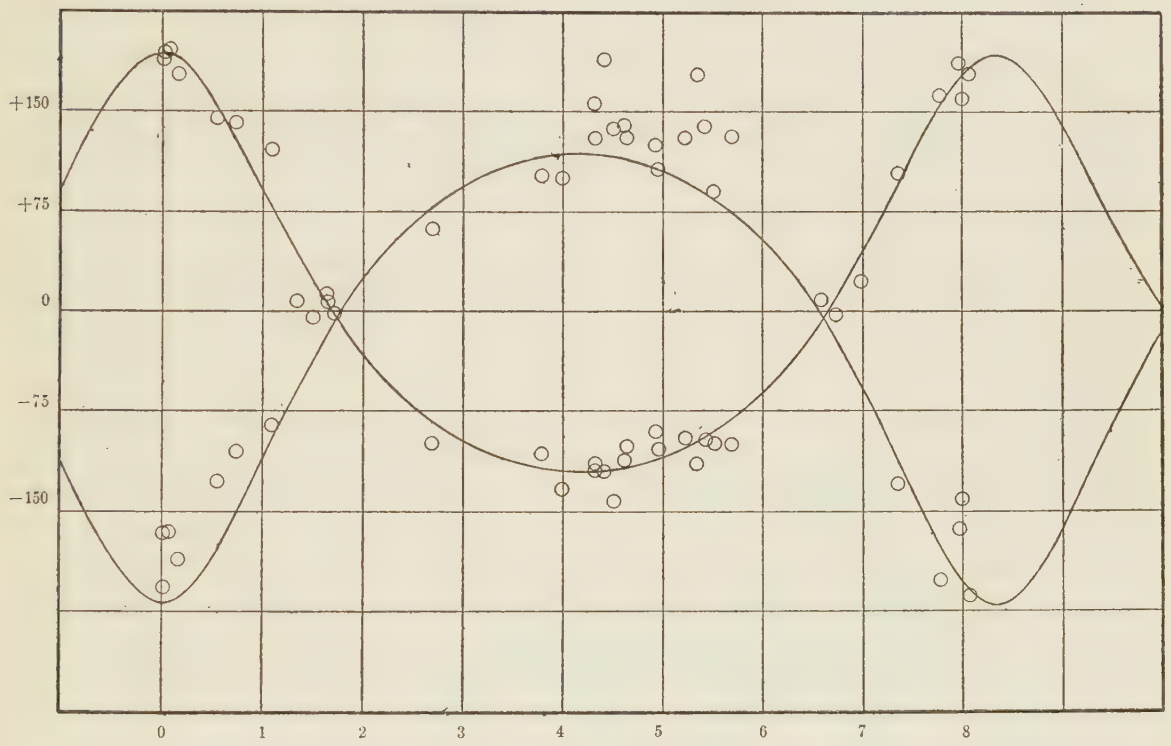

Fig 3—Velocity Curves of H.D. 191201

If we take the minimum value of the mass of the brighter component $13 \cdot 85 \odot$ and assume a temperature for this O9-B0 star of 26,000° T, a value according with Fowler and Milne's latest determination,[1] we obtain a surface brightness by Hertzsprung's method[2] of $-3 \cdot 84$ magnitudes, 34 times the sun, with which Russell's colour index method practically agrees. Some recent work of Mr. Pearce clearly shows that the density of these massive high temperature stars is of the order of $0 \cdot 01$ the sun. However, the star H.D. 1337, for which this was determined, has obviously only relatively recently become a double as the photometric orbit shows the two stars are nearly in contact and it is probably considerably more diffuse than H.D. 191201.

[1] M.N., 84, 509.
[2] Mt. W. Cont., 10, 399.

The eccentricity of H.D. 191201 of 0·26 indicates a considerable advance in the evolutionary stage and hence probably an increase of density. The eclipsing binary Y Cygni, which is of nearly the same type, has a density of 0·17 so that the density of this star probably lies between the extreme values of 0·01 and 0·2. With a surface brightness of −3·84 magnitudes compared to the sun and a mass 13·85 times, the absolute magnitude is readily calculated as −4·2 for a density 0·01; −3·0 for the probable density of 0·05; −2·5 for density of 0·1 and −2·0 for density 0·2.

The absolute bolometric magnitude of a star of mass 13·85⊙ by Eddington's latest method[1] is −3·17, the correction for a temperature of 26,000° being −1·40, making a total of −4·57. The correction to visual magnitudes for this temperature is +2·53, making the calculated visual magnitude −2·04, corresponding to a density of 0·2. As is shown by Mr. Pearce in his discussion of H. D. 1337 where the density is determined by the photometric orbit, the absolute magnitude of the brighter component obtained from Eddington's method is about 2·3 magnitude fainter than that computed from the known mass, density, and surface brightness of that star, and obviously it does not fit on Eddington's curve which appears to suit better the dwarf than the giant stage at these high temperatures and masses.

The apparent magnitude of the pair is 7·12 and the second component, from the relative intensity of the spectra and also considering the relative masses, must be at least 0·2 magnitudes fainter than the primary. This will make the apparent visual magnitude of the primary 7·77.

The well known formula connecting absolute and apparent visual magnitude with parallax gives a parallax of 0″·0011 for absolute magnitude of −2·0, of 0″·0007 for absolute magnitude −3·0 corresponding to the probable density of 0·05, and a parallax of 0″·004 for magnitude −4·2 and density 0·01, distances respectively of 3500, 4700 and 8000 light years. If we take into account the fact that the inclination must be considerably less than 90° else the star would appear variable, and that hence the mass must be increased, while the high density of 0·2 is unlikely, it seems certain that the distance of this star is at least 5000 light years, making it at a greater distance than the average O-type and several times farther than previously ascribed to the B-type stars.

[1] M.N., 84, 310.

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THE ORBITS OF TWO DOUBLE-LINED SPECTROSCOPIC BINARIES

BY W. E. HARPER

Abstract.—The first of the two stars dealt with in this article, Boss 1275, is of type A0 and was announced as a double-lined binary by Adams of the Mount Wilson Observatory in October, 1916. A couple of years later Cannon, at the Dominion Observatory, Ottawa, determined its orbit from forty plates taken there with the single-prismt camera. Unfortunately, as shown herein, the period of 27·43 days is incorrect and the first half of this publication deals with the revision of the orbital elements of this star from plates made at Victoria. The revised period is 2·15165 days and a circular orbit with semi-amplitudes of 113 and 130 kms. per sec. gives a reasonably satisfactory agreement with the observations. The masses of the components multiplied by the cube of the sine of the inclination are respectively 1·7 and 1·5 times that of the sun.

The star Boss 1275, whose right ascension for 1900 was $5^h\ 14^m{\cdot}9$, and declination $+29°\ 29'$, was announced a spectroscopic binary by Adams and investigated by Cannon who, in 1918, published his orbit in the *Publications of the Dominion Observatory*, Volume IV, page 185. The period of 27·43 days obtained by him seemed to be the only possible one, even though some of the observations were in rather ragged agreement with the curve. A couple of years later the writer of this article had occasion to examine the observations and noted that a short period would satisfy most of the observations. At that particular time he had nearly fallen into a similar error of ascribing a long period to what was in reality quite a short period binary. Remembering the trouble experienced by Cannon, with whom he was associated at Ottawa, in the case of the star under consideration he was led to look into it with the resulting conclusion that the period as published was in error. His communication to Cannon on the matter evidently miscarried in the mails and the present writer admits negligence in not drawing the matter to his attention again until recently.

In the course of obtaining spectra of A-type stars for absolute magnitude work the rapid shift of the spectrum lines of this star again emphasized the apparently short period character of the binary, and made it seem advisable to secure the correct period and other orbital elements. As Cannon has been for some time out of spectroscopic work, he asked the writer to undertake the necessary revision of the orbit.

The period suggested by the Victoria plates alone is 2·15 days, which period also satisfies the Ottawa observations much better than the one originally determined. By connecting up the two series of observations it was found that either of two periods was possible, namely 2·15165 or 2·15236 days. The former value was preferred as fewer of the observations fell on the wrong branch of the curve.

22808—1

It was evident that a re-examination of the Ottawa plates was desirable and through the courtesy of the Director, Mr. R. Meldrum Stewart, they were forwarded to Victoria. Previous to their arrival the writer felt reasonably sure of the correctness of the value 2·15165 days for the period and carried through a least-squares solution, combining the observations of the two observatories. As between three and four times as many lines were measured on the Victoria plates as on the Ottawa ones, there was a similar disparity in the weights assigned the two sets of measures. The results are tabulated at the end. The Ottawa plates are all weak in the violet and are sometimes not of the best definition so that if one took an average of all the component lines there would be a likelihood that the components would be assigned as in the previous publication. By paying attention, however, solely to the 4481 line of magnesium—a proceeding warranted by the uniformity of exposure in that region—the writer found that using the period of 2·15165 days the component velocities in every case fell on the proper branch of the curve. With this period the Mount Wilson observations, later secured, were in agreement also, so that this value of the period may be regarded as the correct one.

The accompanying table of observations gives the data of the Victoria observations. Ten or a dozen lines were measured on a plate given unit weight. The last three observations had not been secured when the combined solution for the Ottawa and Victoria plates were made.

Victoria Observations of Boss 1275

Plate	Date G.M.T.	Julian Date	Phase	Component I			Component II		
				Vel.	Wt.	O-C	Vel.	Wt.	O-C
12829	1926 Feb. 13	2,424,560·598	1·233	− 76·4	1	− 6·5	+ 34·5	1	− 3·3
12839	" 13	560·806	1·441	−122·8	1	− 3·9	+ 78·1	1	−15·9
12853	" 22	569·612	1·640	−130·2	1	+ 2·4	+110·6	1	− 0·1
12858	" 22	569·745	1·773	−124·0	1	− 3·5	+ 98·6	1	+ 2·3
12868	" 26	573·651	1·376	− 98·4	1	+ 8·6	+ 78·5	1	− 1·5
12876	" 26	573·753	1·478	−123·6	1	+ 0·5	+124·7	½	+24·7
12898	Mar. 1	576·617	0·039	− 14·3	1	− 7·5			
12904	" 1	576·806	0·228	+ 58·3	1	+ 8·0	− 99·2	1	+ 0·7
12923	" 2	577·685	1·107	− 27·7	1	+ 2·3			
12982	" 5	580·617	1·888	−100·2	1	− 1·5	+ 74·2	1	+ 3·5
12989	" 5	580·781	2·052	− 39·9	1	+12·3			
13006	" 8	583·634	0·601	+ 97·3	1	+ 5·7	−149·8	½	− 2·5
13176	April 5	611·688	0·684	+ 78·2	1	− 5·1	−140·8	1	− 3·0
13296	" 22	628·691	0·473	+ 84·8	1	− 6·7	−145·8	½	+ 1·4
13312	" 24	2,424,630·675	0·305	+ 74·3	1	+ 6·0	−129·9	½	− 9·4

The observations of the two observatories were grouped indiscriminately according to phase into 24 normal places, twelve representing each component. They are not shown here for the reason that the elements so determined were not considered final. In the original determination, while no probable error of a plate is quoted it is of the order of 20 km. per sec. even after the velocity of plate number 8089 has been improved to the extent of 14 km. through the correction of a slip in the computation. This reduces to slightly less than 13 km/sec. for each component for the new elements. The corresponding probable error for the Victoria plates is 5 km/sec.

The greater precision of the Victoria plates made it appear wise to secure a few more to fill up gaps in the curve and then to use solely our own observations in the determination. This was done and the values accepted as final are based upon 12 measures of each component and 3 measures where the lines are superposed. In this solution the elements resulting from the combined solution were used as preliminary values, each observation being treated individually. Corrections of a small order of magnitude were obtained but the resulting eccentricity was so close to zero that another solution was made on the assumption of a circular orbit. Only four quantities were involved, namely, $-\gamma$, K_1, K_2 and (T) the time of closest approach of the main component to the sun. The values adopted as preliminary were:—

$$\begin{aligned} P &= 2{\cdot}15165 \text{ days} \\ e &= 0{\cdot}0 \\ K_1 &= 113 \text{ km.} \\ K_2 &= 130 \text{ km.} \\ (T) &= \text{J.D. } 2{,}421{,}138{\cdot}241 \end{aligned}$$

and by making the following substitutions 27 observation equations were built up.

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K_1 \\ z &= \delta K_2 \\ u &= 292{\cdot}02\ \delta(T) \end{aligned}$$

Observation Equations for Circular Orbit

1	1·000x	−0·997y	+0·000z	−0·085u	− 2·7	= 0
2	1·000	−0·894	+0·000	−0·506	+ 2·8	
3	1·000	−0·697	+0·000	−0·810	+ 1·2	
4	1·000	−0·287	+0·000	−1·082	−12·7	
5	1·000	+0·113	+0·000	−1·123	+ 6·9	
6	1·000	+0·618	+0·000	−0·888	− 8·7	
7	1·000	+0·777	+0·000	−0·711	− 6·7	
8	1·000	+0·982	+0·000	−0·214	+ 6·0	
9	1·000	+0·983	+0·000	+0·208	− 6·4	
10	1·000	+0·910	+0·000	+0·469	+ 4·4	
11	1·000	−0·091	+0·000	+1·125	− 2·8	
12	1·000	−0·443	+0·000	+1·012	+ 6·1	
13	1·000	−0·768	+0·000	+0·723	− 8·6	
14	1·000	−0·876	+0·000	+0·546	+ 3·6	
15	1·000	−0·922	+0·000	+0·436	− 0·8	
16	1·000	+0·000	+0·997	+0·098	− 0·2	
17	1·000	+0·000	+0·894	+0·582	− 1·7	
18	1·000	+0·000	+0·697	+0·932	− 3·2	
19	1·000	+0·000	−0·618	+1·022	− 2·0	
20	1·000	+0·000	−0·777	+0·818	+ 7·9	
21	1·000	+0·000	−0·982	+0·246	− 3·0	
22	1·000	+0·000	−0·983	−0·239	+ 0·8	
23	1·000	+0·000	−0·910	−0·540	+ 1·4	
24	1·000	+0·000	+0·443	−1·165	+ 3·3	
25	1·000	+0·000	+0·768	−0·832	+ 1·9	
26	1·000	+0·000	+0·876	−0·628	+16·5	
27	1·000	+0·000	+0·922	−0·372	−24·1	

From these there resulted the following normal equations:—

25·000x	−1·592y	+2·237z	− 1·269u	−11·600	=	0
	8·529	+0·000	− 1·381	− 1·455		
		6·735	− 1·131	+ 0·292		
			11·545	+ 0·431		

which gave corrections as follows:—

$\delta\gamma$ = +0·50 km.
δK_1 = +0·27 km.
δK_2 = −0·20 km.
$\delta(T)$ = ±0·000 days

The solution was hardly justified, as the corrections show, but the time consumed was small. The probable error of a plate for component I is ±4·3 and for component II ±5·6 km./sec.

ELEMENTS OF THE ORBIT

Element		Combined Solution	Victoria Plates = Final
Period	P	2·15165 days	2·15165 days.
Eccentricity	e	0·013	0·000
Longitude of apse	ω_1	180°·4	
Longitude of apse	ω_2	0°·4	
Velocity of system		−17·18 km	−19·70 km. ±0·98 km.
	(T)		J.D. 2,421,138·241 ±0·005.
Periastron passage	T	J.D. 2,421,139·858	
Semi-amplitude primary	K_1	112·85 km	113·27 km. ±1·67 km.
Semi-amplitude secondary	K_2	126·05 km	129·80 km. ±1·89 km.
$a_1 \sin i$			3,351,400 km.
$a_2 \sin i$			3,840,400 km.
$m_1 \sin^3 i$			1·71 ⊙
$m_1 \sin^3 i$			1·50 ⊙

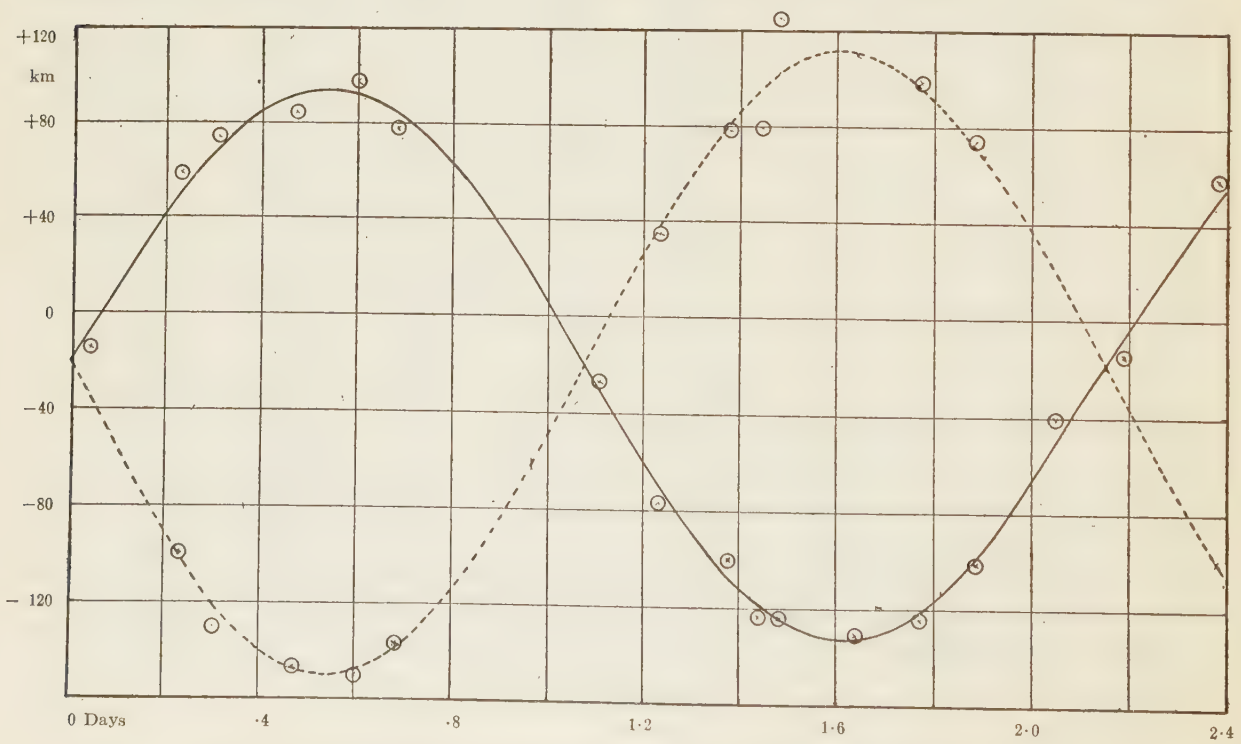

Fig. 1.—Velocity Curves of Boss 1275, Showing Victoria Individual Observations.

The curves shown represent the final elements, individual observations being plotted. The full curve represents component I and the dotted one component II.

H.R. 2962

Abstract.—This star's binary character has not hitherto been announced. The orbit is based on 25 spectrograms secured during the past three years. The spectrum of the secondary has been measured on 13 plates and, while of lesser intensity, is about of the same type as the main one, F3 or thereabouts. It was with difficulty the lines were resolved over most of the curve as the semi-amplitudes of velocity variation are only 45 and 52 kms. per sec. The period is 31·5 days and eccentricity ·208.

The star H.R. 2962 whose right ascension for the epoch 1900 was $7^h\ 36^m \cdot 2$ and declination $+34°\ 14'$, was first observed here on March 17, 1924. The fuzzy character of the lines made one strongly suspicious that it might be a binary and this suspicion was confirmed by the third plate whereon the spectrum lines were definitely resolved. Twenty-eight plates have been secured during the three seasons but three of these are omitted from consideration by reason of the complex nature of the lines due to partial superposition of the two spectra. The plates were all made with the single-prism camera whose dispersion at $H\gamma$ is 29 angstroms per millimetre.

The star is listed in the Henry Draper catalogue as of type F0 and of visual magnitude 6·00. In spectra not completely resolved or nearly superposed which, with the single-prism dispersion used, would constitute fully 75 per cent of the time, the type suggested would be F0. Where exactly superposed, however, the type appears more nearly like F3 which type has been accepted for both components.

When the period and general form of the velocity curves were obtained it was seen that there was considerable eccentricity in the orbit. Since the maximum separation was not very much greater than the limit of resolution for the single-prism it necessitated using a narrower slit-width than ·051 mm. as generally used. With the narrower width of ·038 mm. it was possible to get the lines resolved around apastron phase where the separation was not over 80 km. Five plates were secured around this phase with half a dozen or more lines in the violet region clearly resolved and these results added materially to the accuracy of the elements as determined.

The following table gives the data of the observations. Greenwich Mean Time, as understood prior to 1925, is used throughout and no correction is to be made to the dates. The phases are reckoned from the value of periastron passage finally adopted using the period of 31·50 days. The residuals are scaled from the final curve.

Observations of H.R. 2962

Plate	Date G.M.T.	Julian Day	Phase	Component I			Component II		
				Vel.	Wt.	O-C	Vel.	Wt.	O-C
9765	1924 Mar. 17	2,423,862·709	9·76	−54·5	1	− 4·0			
9798	" 24	3,869·751	16·80	−24·9	1	+ 8·5			
10948	Nov. 24	4,114·878	9·93	−47·8	1	+ 2·8	+34·0	½	+ 1·6
11103	Dec. 23	4,143·958	7·51	−48·1	1	− 2·1			
11177	1925 Jan. 23	4,174·845	6·90	−31·9	¾	+11·0			
11262	Mar. 6	4,216·759	17·31	−22·8	1	+ 9·1			
11309	" 14	4,224·809	25·36	+21·4	1	− 1·3	−52·6	1	+ 1·1
11322	" 16	4,226·771	27·32	+37·3	2	+ 1·5	−67·9	1	+ 0·1
11486	April 13	4,254·694	23·74	− 1·8	1	−12·6			
11520	" 20	4,261·682	30·73	+39·1	1	+ 6·1	−66·0	1	− 1·0
11606	May 11	4,282·730	20·28	−10·0	1	+ 3·6			
12782	1926 Jan. 25	4,541·901	27·45	+44·9	1	+ 8·3	−68·3	½	+ 0·3
12840	Feb. 13	4,560·848	14·90	−38·2	1	+ 2·8			
12903	Mar. 1	4,576·772	30·82	+25·8	½	− 6·4	−74·2	½	−10·0
13009	" 8	4,583·795	6·35	−23·6	¾	+17·6			
13031	" 13	4,588·668	11·22	−44·1	1	+ 5·9			
13145	" 29	4,604·745	27·30	+35·4	1	− 0·4	−71·5	1	− 3·7
13154	" 31	4,606·689	29·24	+37·0	1	− 2·3	−76·4	1	− 4·4
13170	April 1	4,607·706	30·26	+35·9	1	− 0·1	−69·2	1	− 0·6
13177	" 5	4,611·709	2·76	−13·8	1	− 6·8			
13188	" 6	4,612·755	3·80	− 4·6	1	+14·4			
13226	" 11	4,617·710	8·76	−53·8	1	− 4·6	+36·2	½	+ 6·2
13231	" 12	4,618·694	9·74	−58·4	1	− 7·8	+28·4	1	− 3·6
13232	" 12	4,618·722	9·77	−58·6	1	− 8·0	+26·9	1	− 5·1
13245	" 13	2,424,619·818	10·87	−51·3	1	− 0·9	+29·3	1	− 3·0

Preliminary Elements

$$
\begin{aligned}
P &= 31\cdot50 \text{ days} \\
e &= 0\cdot22 \\
\omega_1 &= 50^\circ \\
\omega_2 &= 230^\circ \\
K_1 &= 45 \text{ km.} \\
K_2 &= 52 \text{ km.} \\
\gamma &= -10\cdot86 \text{ km.} \\
T &= \text{J.D. } 2{,}423{,}884\cdot56
\end{aligned}
$$

The foregoing elements obtained graphically were used to build up fifteen observation equations of the usual form from which to deduce improved values of the elements. The observations were first grouped into normal places according to phase, eleven representing component I and four component II.

NORMAL PLACES

	Mean Phase		Mean Vel.	Wt.	Residual O-C	
	Prel.	Final			Prel.	Final
1	9·69	9·80	−54·8	4	− 5·3	− 4·4
2	10·94	11·05	−47·7	2	+ 0·7	+ 2·6
3	14·79	14·90	−38·2	1	− 0·7	+ 3·0
4	16·94	17·05	−23·8	2	+ 3·9	+ 7·2
5	21·90	22·01	− 5·9	2	− 8·5	− 2·5
6	25·25	25·36	+21·4	1	− 5·0	− 1·3
7	27·23	27·34	+38·7	4	+ 1·3	+ 2·9
8	30·07	30·18	+35·7	3½	− 0·8	− 1·1
9	3·18	3·29	− 9·2	2	+ 7·0	+ 1·7
10	6·51	6·62	−27·8	1½	+15·6	+11·0
11	8·02	8·13	−51·0	2	− 2·9	− 3·2
12	9·82	9·93	+29·9	4	− 3·8	− 2·5
13	25·25	25·36	−52·6	1	+ 1·3	+ 1·1
14	27·23	27·34	−69·4	2½	− 2·7	− 1·6
15	30·07	30·18	−71·1	3½	− 5·5	− 2·1

The mean velocities given above are those resulting from the combination of velocities as actually measured. Before proceeding to the solution, however, five of these were corrected by small amounts to allow to some extent for errors inherent in them by reason of the partial blending of the lines. On the average the lines of the main spectrum are probably fifty per cent more intense than are those of the secondary. Thus around the crossing points the measured velocities will fall closer to the main than to the secondary curve and it was to offset to some extent this tendency of the velocities to hug the γ-line that corrections were made. The corrections made were based on the relative strengths of the lines just suggested and on the particular phase of the group and err rather on the side of being too conservative. To the numbers 4, 5, 6, 9 and 10 were added $-1\cdot0$, $+2\cdot0$, $+1\cdot0$, $-2\cdot0$ and $-3\cdot0$ km. respectively and it is felt that these reduced residuals produce in the solution a higher degree of accuracy for the elements than if the residuals had been left as measured.

For the sake of homogeneity the following transformations were made in the equations of the Lehmann-Filhés form as adapted* for double line spectra. The weights of each are given in the table of Normal Places.

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K_1 \\ z &= \delta K_2 \\ u &= 100\cdot\delta e \\ v &= -100\cdot\delta\omega \\ w &= 21\cdot490\ \delta T \end{aligned}$$

* Dominion Observatory Publications, Vol. I, page 327.

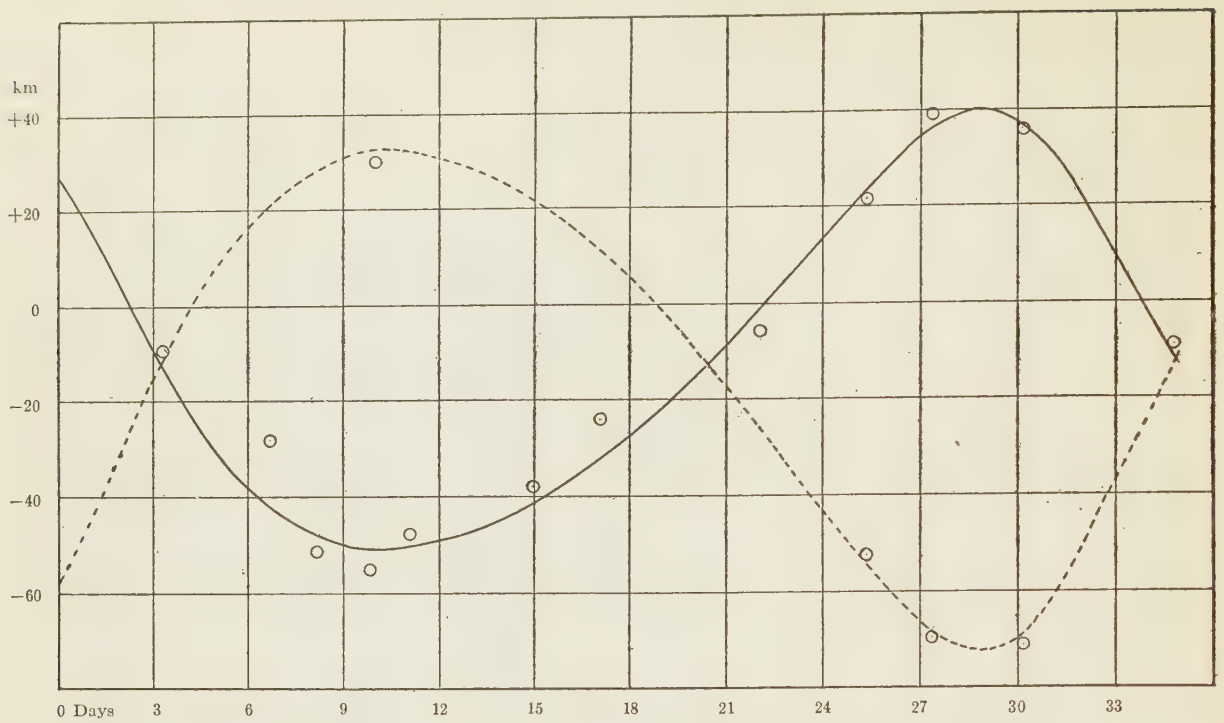

Fig. 2.—Radial Velocity Curves of H.R. 2962 Showing Grouped Observations.

Observation Equations for H.R. 2962

1.....	1·000x	−0·859y	+0·000z	+0·309u	+0·062v	−0·010w	+ 5·3	= 0
2.....	1·000	−0·835	+0·000	+0·404	−0·022	−0·067	− 0·7	
3.....	1·000	−0·593	+0·000	+0·361	−0·230	−0·187	+ 0·7	
4.....	1·000	−0·375	+0·000	+0·178	−0·310	−0·236	− 2·9	
5.....	1·000	+0·299	+0·000	−0·366	−0·369	−0·326	+ 6·5	
6.....	1·000	+0·827	+0·000	−0·386	−0·252	−0·311	+ 4·0	
7.....	1·000	+1·073	+0·000	−0·048	−0·088	−0·188	− 1·3	
8.....	1·000	+1·053	+0·000	+0·475	+0·260	+0·265	+ 0·8	
9.....	1·000	−0·119	+0·000	−0·506	+0·511	+0·551	− 5·0	
10.....	1·000	−0·723	+0·000	−0·171	+0·302	+0·210	−12·6	
11.....	1·000	−0·829	+0·000	+0·094	+0·184	+0·089	+ 2·9	
12.....	1·000	+0·000	+0·858	−0·372	−0·061	+0·019	+ 3·8	
13.....	1·000	+0·000	−0·827	+0·446	+0·291	−0·359	− 1·3	
14.....	1·000	+0·000	−1·073	+0·055	+0·101	−0·217	+ 2·7	
15.....	1·000	+0·000	−1·053	−0·548	−0·301	+0·306	+ 5·5	

From these were formed the normal equations:—

3·600x	−0·003y	−0·376z	−0·078u	+0·001v	+0·024w	+4·610	= 0
	1·650	+0·000	−0·093	−0·040	−0·036	−0·072	
		1·037	+0·022	+0·039	−0·019	−1·337	
			0·451	+0·093	−0·076	−0·704	
				0·203	+0·103	−1·770	
					0·213	−0·640	

which resulted in corrections as follows:—

$$\begin{aligned} \delta\gamma &= -1{\cdot}25 \text{ km.} \\ \delta K_1 &= +0{\cdot}18 \text{ km.} \\ \delta K_2 &= +0{\cdot}43 \text{ km.} \\ \delta e &= -0{\cdot}012 \\ \delta\omega &= -6^\circ{\cdot}0 \\ \delta T &= -0{\cdot}11 \text{ day} \end{aligned}$$

This solution reduced the sum of the squares for the normal places from 623·8 to 513·5. The probable error of a normal place of unit weight is ±5·09 km. per sec. and this value was used to determine the probable errors of the elements which are attached.

Final Elements

$$\begin{aligned} P &= 31{\cdot}50 \text{ days} \\ e &= 0{\cdot}208 \pm 0{\cdot}045 \\ \omega_1 &= 44^\circ{\cdot}0 \pm 4^\circ{\cdot}0 \\ \omega_2 &= 224^\circ{\cdot}0 \pm 4^\circ{\cdot}0 \\ K_1 &= 45{\cdot}18 \text{ km.} \pm 1{\cdot}94 \text{ km.} \\ K_2 &= 52{\cdot}43 \text{ km.} \pm 2{\cdot}49 \text{ km.} \\ \gamma &= -12{\cdot}11 \text{ km.} \pm 0{\cdot}42 \text{ km.} \\ T &= \text{J.D. } 2{,}423{,}884{\cdot}45 \pm 0{\cdot}33 \text{ days} \\ a_1 \sin i &= 19{,}142{,}000 \text{ km.} \\ a_2 \sin i &= 22{,}214{,}000 \text{ km.} \\ m_1 \sin^3 i &= 1{\cdot}53\odot \\ m_2 \sin^3 i &= 1{\cdot}32\odot \end{aligned}$$

Using all residuals the probable error of a single plate is for component I ±4·9 km. per sec. and for component II ±2·6 km. per sec. Discarding seven where the spectra are partially superposed the value for component I becomes ±3·4. This latter value of course gives a more correct idea of the accuracy of the observations.

Considering the best plates where the spectra are superposed the relative intensities of six pairs of lines give absolute magnitudes as follows: 3·3, 3·0, 2·6, 2·9, 3·3, and 3·4. The mean is 3·1 and, making some allowance for the effect of the secondary, a parallax of 0″·02 is deduced.

The accompanying graph represents the final values of the elements. Grouped observations are shown with the dotted curves representing the secondary component.

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THE ABSOLUTE DIMENSIONS OF THE O-TYPE ECLIPSING VARIABLE H.D. 1337

By J. A. Pearce

ABSTRACT

The subject of this paper is an eclipsing variable of exceptional mass and exceedingly high temperature. With actual masses of 36·3 and 33·8 times the sun, *H.D. 1337*, spectral type O8·5n, stands at present at the head of the limited list of fourteen systems whose absolute dimensions have been derived by combining the elements of their spectroscopic and photometric orbits. The paper is divided into three parts.

Part I—*The Spectroscopic Orbit.*—Brief reference is made to the discovery and previous investigation of this spectroscopic binary. The spectrum is described and classified as O8·5n. A table of the estimated intensities of the spectral lines observed is given. Twenty-six plates in which the spectra of both components are measured form the basis of the spectroscopic discussion. An accurate period is found with the assistance of observations taken at the Mount Wilson Solar Observatory during the years 1914–1916. The time of periastron passage is fixed and the remaining elements K_1, K_2, e, ω and γ are corrected by least-squares. The principal elements are : P = 3·52341 days, e = 0·037, ω = 210°·16, $K_1 + K_2$ = 453 km., γ = — 29·34 km., $(m_1 + m_2) \sin^3 i$ = 34·0 ⊙, $a \sin i$ = 31·5 ⊙. The probable errors of the orbits are ±7·0 and ±8·2 km. respectively. The strong sharp (H) and (K) lines of ionized calcium which show no periodic oscillation have a mean velocity of −22·43 ±0·34 km. These lines originate in an interstellar cloud whose radial velocity of approach is 15 km.

Part II—*The Photometric Orbit.*—The photometric observations of Guthnick are discussed. The corrected period harmonizes the spectroscopic and photometric phases within the probable errors of the spectroscopic orbit. The observed *β Lyrae* light curve is interpreted, the ellipticity constant determined and the observed magnitudes rectified for the periastron and ellipticity effects. It is shown that the photometric elements cannot be derived from the photometric curve alone. The solution is effected by introducing data from the spectroscopic orbit. The orbital eccentricity, as determined from the photometric curve, is shown to agree with the spectroscopic value. The inclination of the orbital plane i, and the eccentricity of figure of the component stars ϵ, are verified by an independent method. The light variation, which is less than 0·20 magnitudes, results from two ellipsoidal stars practically in contact, revolving in a slightly elliptic orbit whose plane is inclined at the angle of 38° to the plane containing the line of sight.

Part III—*The Physical Characteristics of the System.*—By combining the elements of the spectroscopic and photometric orbits the actual masses and dimensions of the stars are shown to be: m_1 = 36·3 ±1·7 ⊙, m_2 = 33·8 ±1·6 ⊙, r_1 = 23·8 ⊙, r_2 = 15·5 ⊙, a = 40·1 ⊙, ρ_1 = 0·0027 D⊙, ρ_2 = 0·0091 D⊙. The masses of the O-type stars are discussed. By Struve's method it is shown that the average single O-type star has a mass of 38 ⊙, two and a half times more massive than the average early B star, 15 ⊙, and seven times more massive than the average single class B star, 5 ⊙. The dwarf O-type system *Y Cygni* is compared with the giant system *H.D. 1337*, and reasons are stated for accepting the mean density of the class O stars as 0·01 D⊙. Bolometric absolute magnitudes of $-8^m \cdot 82$ and $-7^m \cdot 31$ are deduced for the component stars by the luminosity method. Eddington's theory gives residuals of (O–C) = $-2^m \cdot 3$ and $-1^m \cdot 0$ respectively. A recomputation of the absolute magnitudes of the eclipsing variable systems gives average residuals of $\pm 0^m \cdot 4$ for the brighter components and $\pm 1^m \cdot 7$ for the fainter components. The hypothetical parallax is 0″·00032, total proper motion is 0″·0096, and space velocity is 146 km. per second. A comparison is made between the strikingly similar systems *B.D. 6°·1309* and *H.D. 1337*. The paper closes with a brief summary of the more interesting details of this unusual system.

24499—1

PART I.—THE SPECTROSCOPIC ORBIT

1. Discovery and Previous Investigation

The binary nature of the star *H.D. 1337 = Boss 46*, 1900 α $0^h\ 12^m.5$, 1900 δ 50° 53′ (Cassiopeia), vis. mag. 6·22 P.D., spectral type O8·5n, was first detected from spectrograms obtained at Mount Wilson, and was announced in the *Annual Report of the Observatory* for the year 1916. An orbit for the brighter component of this diffuse lined binary was computed by Adams and Stromberg[1] who grouped their 34 observations into 11 normal places based upon the period 3·5225 days. The faint secondary spectrum was measured on a number of plates, but the observations were too few to determine the semi-amplitude of its oscillation. The sharp lines of ionized calcium gave indications of a variation in velocity of about 20 km. with the same period as that shown by the hydrogen and helium lines. The velocity of calcium was 20 km. more positive than the velocity of the system, as derived from the other lines. On account of its periodic variation, the authors favoured the view that the calcium gas producing these lines was connected with the stars, and that the difference in the apparent motion of the system was not to be interpreted wholly on the basis of velocity.

2. The Victoria Observations

H.D. 1337 occurs on the program of class B stars now being investigated at this Observatory. The first plate obtained showed double lines of over 300 km. relative separation. In all, 34 observations were secured with the I-prism spectroscope, two-thirds of the number being taken with the short-focus camera having a linear dispersion of 49A per mm. at Hγ. The remaining plates were secured with the medium-focus camera

TABLE I—JOURNAL OF THE VICTORIA OBSERVATIONS OF H.D. 1337

No.	Plate	Date	J. D. 2,424,000 +	Primary		Secondary		Calcium		Remarks
				Velocity	Lines	Velocity	Lines	Velocity	Lines	
		1924								
1	10449	Aug. 5	003·9424	−178·9	14	+130·1	12	−19·5	2	IM, fair, over-exposed.
2	10921	Nov. 8	098·8031	−240·2	10	+189·1	9	−23·8	2	IS, good.
3	10928	" 9	099·8236	+111·6	14	−181·0	11	−21·1	2	IS, good.
4	10958	" 26	116·6927	−160·9	8	+111·1	5	−19·8	2	IS, fair, remeasured.
* 5	10990	" 28	118·7451	− 4·8	16			−20·4	2	IM, good, lines blended.
6	10996	" 29	119·6966	−254·2	9	+204·2	8	−29·6	2	IS, good.
* 7	11014	Dec. 7	127·7070	+ 0·5	16			−16·3	2	IS, good, lines blended.
8	11035	" 18	138·6882	+139·2	12	−191·3	12	−23·8	2	IS, good.
9	11049	" 19	139·7305	+ 63·4	12	−138·3	10	−21·4	2	IS, fair, remeasured.
*10	11064	" 21	141·6611	− 42·6	15			−16·8	2	IS, good, lines blended.
11	11115	" 24	144·6903	−211·5	11	+170·9	9	−21·5	2	IS, good.
12	11120	" 25	145·7125	+123·6	11	−200·3	9	−17·1	2	IS, good.

[1] The references are found at the end of the section, p. 284.

* Not used in least-squares solution.

TABLE I—JOURNAL OF THE VICTORIA OBSERVATIONS OF H.D. 1337—*Concluded.*

No.	Plate	Date	J. D. 2,424,000 +	Primary		Secondary		Calcium		Remarks
				Velocity	Lines	Velocity	Lines	Velocity	Lines	
		1925								
13	11131	Jan. 8	158·6397	−240·0	14	+211·5	11	−24·8	2	IS, good.
14	11144	" 15	165·6000	−258·8	17	+209·3	13	−16·4	2	IS, good.
15	11186	" 25	175·5965	−166·6	14	+118·4	10	−23·5	2	IS, fair, over-exposed.
16	11200	Feb. 14	195·6027	+171·5	12	−253·1	12	−21·2	2	IS, fair, remeasured.
17	11217	" 17	198·6393	+147·4	16	−212·4	16	−18·7	2	IM, fair, remeasured
*18	11222	". 22	203·6347	− 44·0	8					Poor, lines blended.
*19	11234	Mar. 6	215·6562	− 51·4	13			−23·4	2	IS, fair, lines blended
20	11892	July 16	347·9805	− 95·3	12	+ 45·6	11	−19·6	2	IS, fair. Seed 23. Fainter not well determined.
*21	11931	" 21	352·9743	− 35·2	14			−19·6	2	IS, fair, lines blended
22	11937	" 23	354·9764	− 72·8	14	+ 31·6	11	−21·4	2	IS, good, Remeasured, barely resolved.
23	11943	" 24	355·9459	−234·3	14	+227·9	12	−17·5	2	IS, fair. Seed 23. Fainter not well defined.
24	11959	" 26	357·9812	+111·9	11	−167·9	9	−23·2	2	IS, fair, remeasured.
25	11973	" 27	358·9750	−237·0	19	+179·2	16	−20·7	2	IM, good.
*26	11988	" 28	359·9875	− 46·6	13			−22·6	2	IM, good, lines blended.
*27	11999	" 30	361·9784	− 8·1	22			−20·6	2	IM, good, lines blended.
28	12020	" 31	362·9951	−233·4	14	+196·5	13	−20·0	2	IM, good.
29	12051	Aug. 4	366·9895	− 86·5	17	+ 43·8	15	−18·2	2	IM, good, barely resolved.
30	12083	" 7	369·9708	−250·5	17	+208·1	14	−22·4	2	IM, good.
31	12091	" 8	370·9229	+ 65·1	16	−127·7	14	−19·0	2	IM, fair, remeasured
32	12100	" 16	378·7868	+160·1	18	−237·0	18	−17·5	2	IM, good.
33	12111	" 16	379·0174	+142·8	13	−208·8	13	−23·0	2	IM, good, fainter remeasured.
34	12129	" 19	381·9500	+186·1	18	−255·2	16	−21·8	2	IM, good.

giving a linear dispersion of 29A per mm. at Hγ. The data relating to the observations are contained in Table I, which is self-explanatory. The emulsion used was Eastman 40, except where stated in the remarks column. The measures were made on the usual micrometer engine, constructed by Toepfer, having a binocular attachment. Nearly one-third of the plates were remeasured, the weighted means being adopted. The asterisks in column 1 of the table indicate those plates which were not used in the least-squares solution on account of the blending of the lines. These single-lined plates are shown as crossed circles on the velocity curves, Fig. 1.

3. The Spectrum

The spectrum of the star is classified in *H.A.*, Vol. 50 as A, but this is revised to B0 in the *Henry Draper Memorial,* which contains the following remark: "The lines show very slight contrast to the continuous spectrum." Due probably to the appearance of the iron line λ 4549, the spectrum was classified at Mount Wilson as B3p. This line

has not been observed on our plates. From the Yerkes spectrograms Struve[3] calls the star B2. A careful estimation of the intensity of all the absorption lines visible on the first three single-lined plates is tabulated in Table II. The hydrogen line Hγ of equal intensity on plates 11014, 11064, was taken as a standard and the remaining lines were referred to it. In this comparison an artificial scale as described by Harper and Young[4] was helpful in obtaining the relative intensities. The intensity ratios used in the classification of the O-type stars by H. H. Plaskett[5] are given in the fourth column of the table, and from these criteria it is evident that the type is intermediate between O8 and O9. Both stars appear to have identical spectra, the symbol ‡ in Table II denoting those lines measured as double on an average plate. From our plates, therefore, we would assign the type O8·5n–O8·5n. The brighter lines are estimated to be 2·6 times as intense as the fainter lines.

TABLE II—THE SPECTRUM OF H.D. 1337

Wave-length	Atom	Intensity				Intensity Ratio	Type
		Plate 10990	Plate 11014	Plate 11064	Mean		
4922	He	2	2	3	2·3	$\frac{4471}{4541} = 2{\cdot}33$	O8·5
‡4861	H	8	9	9	8·7		
‡4713	He	3	2	2	2·3	$\frac{4541}{H\gamma} = 0{\cdot}28$	O8·2
‡4686	He+	5	4·5	4	4·5	$\frac{4088}{4097} = 1{\cdot}35$	$\frac{O8{\cdot}8}{O8{\cdot}5}$
4654	?	2	–	2	1·3		
4651	C+ +	5	4	3	4·0	Intermediate between O8 and O9.	
4641	N+	2	1	–	1·0		
4634	N+	2	1	–	1·0		
‡4542	He+	3	2	3	2·7		
4524	N+	1	2	1	1·3		
4515	N+	3	2	2	2·3		
4511	N+	2	2	2	2·0		
4481	Mg+	faint	faint	–	0·7		
‡4471	He	6	6	7	6·3		
‡4388	He	3	3	3	3·0		
‡4379	N+	2	2	2	2·0		
‡4340	H	9	10	10	9·7		
4267	C+	faint	faint	–	0·7		
4254	S?	faint	faint	–	0·7		
4200	N+,	3	2	3	2·7		
‡4144	He	4	4	4	4·0		
4121	He	2	2	2	2·0		
‡4116	Si+ + +	3	3	4	3·3		
4103	N+	–	–	1·5	0·5		
‡4101	H	9	12	12	11·0		
4097	N+	4	4	4·5	4·2		
‡4089	Si+ + +	5	6	6	5·7		
‡4026	He	7	8	9	8·0		
4009	He	1	3	2	2·0		
3970	H	8	9	9	8·7		
3968	Ca+ (H)	13	14	14	13·7		
3934	Ca+ (K)	15	15	15	15·0		

‡ Measured double in an average plate.

The spectral lines are diffuse and lacking in contrast, as noted above, doubtless due to the superposition of the continuous spectrum of the one star upon the absorption lines of the other. Apart from this effect, the single-lined plates show the typically nebulous lines of an O-type star. The (H) and (K) lines of ionized calcium are sharp and narrow, quite normal for this class, although their characteristic appearance in the early B's and in the O's has hitherto been referred to as abnormal. The contrast in the appearance of these lines is well shown by the probable errors of their measurement, that of the hydrogen and helium lines being $\pm 7 \cdot 0$ km. for the brighter star, and $\pm 8 \cdot 2$ km. for the fainter star, while the probable error of the calcium lines is $\pm 1 \cdot 9$ km.

4. The Period

With the assistance of some of the Mount Wilson observations taken during the years 1914–1916, the preliminary value of the period was easily extended to the fifth decimal of a day. With his usual kindness, Dr. Adams forwarded the measures of their first twelve observations, which are given in Table III. The writer wishes to express his indebtedness for these measures, since his own observations, taken over a comparatively short interval, appeared to be satisfied by the shorter period. There is, however, no doubt as to the correctness of the revised value. Five of these early observations could not be used, as they fell outside our preliminary curve, or at a phase when the two spectra were superposed and the measures uncertain. The representation of the remaining seven observations of the primary star on our revised curve is shown in Table IV.

TABLE III—EARLIEST MOUNT WILSON OBSERVATIONS OF H.D. 1337

No.	Plate	Date	G.M.T.	J.D. 2,420,000 +	Velocity		
					H and He	Ca+	Sec. Comp.
			h m				
1	Y3950	1914 Dec. 25	16 10	0492·6736	+140	−13·1	
2	4305	1915 Aug. 18	00 00	0728·0000	+126	−23·3	−161
3	4849	1916 May 20	23 42	1004·9875	−278		+155
4	4854	May 21	23 27	1005·9771	+ 1		
5	4916	July 10	23 13	1055·9674	+233	− 9·1	−154
6	4922	July 11	23 16	1056·9694	− 65	− 7·5	− 20
7	5016	Aug. 18	20 51	1094·8688	+192		−193
8	5018	Aug. 18	23 40	1094·9861	+163		
9	5029	Sept. 9	00 03	1116·0021	+185		−167
10	5034	Sept. 9	23 48	1116·9917	−125		− 30
11	5287	Dec. 4	17 15	1202·7188	−196	−49·1	
12	5338	1916 Dec. 10	18 03	1208·7521	−141	−37·0	

TABLE IV—REPRESENTATION ON PRELIMINARY CURVE

Observation	On Curve	Interval	Rev.	Period	Wt.
1	4002·0000	3509·3264	996	3·5234201	4
2	4004·7280	3276·7280	930	3·5233634	4
7	4005·1480	2910·2792	826	3·5233404	2
8	4005·3968	2910·4107	826	3·5234996	3
9	4005·1480	2889·1457	820	3·5233487	2
11	4003·8304	2801·1116	795	3·5234108	4
12	4002·8360	2794·0839	793	3·5234349	4

The resulting period is $3^{d}\cdot52341 \pm 0\cdot00003$, and this is adopted as final, since it is well known that a period determined in this manner after upwards of a thousand revolutions have elapsed is more accurate than that defined by the least-squares solution. It remains to show whether this revised period will harmonize the photometric observations, since the observed time of minimum light should coincide with the time of eclipse computed from the spectroscopic data, within the errors of observation. This will be considered in Part II. The Mount Wilson observations are represented in the graph below as barred circles. They fit the curve with a probable error of $\pm 5\cdot4$ km., over $1\cdot5$ km. smaller than the probable errors of either the present or the former solution. The observations might have been included in the solution and given high weight, but for the sake of uniformity they were not used.

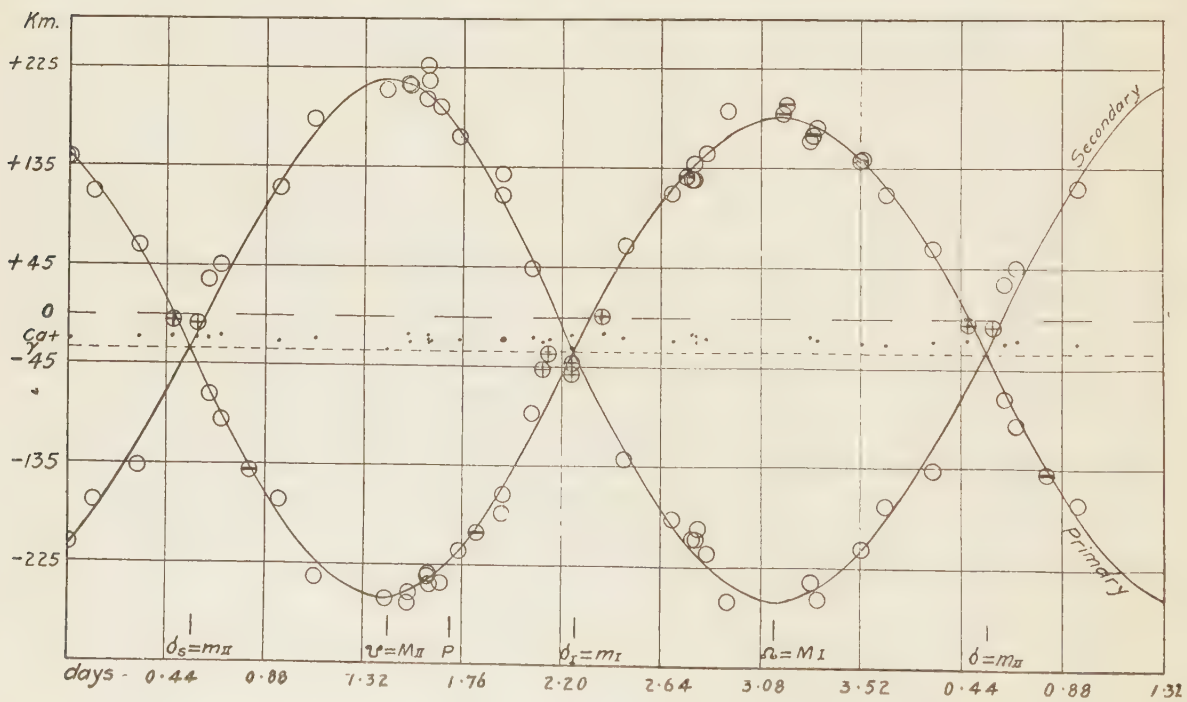

Fig. 1.—Velocity Curves of H.D. 1337.

5. The Solution

Preliminary elements were derived by the usual method of superposing curves computed for different sets of e and ω upon the plotted observations. These elements are shown in Table VI. The time of periastron passage was fixed at J.D. 2,424,003·703 G.M.T. owing to the small eccentricity. The Lehmann-Filhés equation of condition then takes the form:

$$\delta\gamma + (\cos u_1 + e\cos\omega_1)\,\delta K_1 + \left[\cos\omega_1 - \frac{\sin u_1 \sin v_1\,(2 + e\cos v_1)}{1 - e^2}\right] K_1\,\delta e_1$$

$$-(\sin u_1 + e\sin\omega_1)\,K_1\,\delta\omega_1 = \delta V$$

and a similar expression for the secondary spectrum. Adopting the following substitutions the observation equations in Table V were formed for the 52 residuals:

$$\begin{aligned} \text{u} &= \delta\gamma \\ \text{w} &= \delta K_1 \\ \text{x} &= \delta K_2 \\ \text{y} &= 1000\delta e \\ \text{z} &= -1000\delta\omega \end{aligned}$$

TABLE V—OBSERVATION EQUATIONS—H.D. 1337

Primary	Wt.						
11	1·0	1·000u	−0·842w	.....	−·167y	−·130z	− 4·7n = 0
4	0·7	1·000	−0·587	.....	−·030	−·186	+ 0·9
1	0·5	1·000	−0·586	.....	−·029	−·186	+19·1
29	0·3	1·000	−0·370	.....	+·077	−·210	−25·7
31	0·7	1·000	+0·365	.....	+·168	−·206	−15·6
3	1·0	1·000	+0·671	.....	+·115	−·161	+ 5·3
12	0·7	1·000	+0·768	.....	+·055	−·137	+14·8
8	1·0	1·000	+0·792	.....	+·038	−·130	+ 4·2
17	1·0	1·000	+0·840	.....	−·001	−·113	+ 6·8
34	0·7	1·000	+0·907	.....	−·069	−·082	−17·2
32	0·7	1·000	+0·944	.....	−·220	+·050	+16·9
16	1·0	1·000	+0·928	.....	−·219	+·063	+ 1·9
33	1·0	1·000	+0·780	.....	−·163	+·127	− 1·8
24	0·7	1·000	+0·665	.....	−·102	+·156	+ 3·6
9	0·7	1·000	+0·378	.....	+·045	+·198	−11·0
22	0·7	1·000	−0·150	.....	+·210	+·215	+ 9·0
20	0·7	1·000	−0·238	.....	+·218	+·212	+12·2
15	0·7	1·000	−0·674	.....	+·140	+·164	−12·6
25	0·7	1·000	−0·853	.....	+·034	+·120	+18·5
6	1·0	1·000	−1·026	.....	−·189	−·002	− 2·4
14	1·0	1·000	−1·010	.....	−·218	−·043	+ 5·8
30	1·0	1·000	−1·007	.....	−·218	−·046	− 1·7
23	0·7	1·000	−0·973	.....	−·219	−·074	−10·7
28	0·7	1·000	−0·972	.....	−·218	−·075	−11·2
13	1·0	1·000	−0·968	.....	−·218	−·077	− 3·9
2	1·0	1·000	−0·922	.....	−·203	−·101	+ 6·5

TABLE V—OBSERVATION EQUATIONS—H.D. 1337—*Concluded*

Secondary	Wt.						
11	0·7	1·000u	.....	+0·842x	+·179y	+·140z	− 2·7n = 0
4	0·5	1·000	.....	+0·587	+·032	+·199	− 3·2
1	0·3	1·000	.....	+0·586	+·031	+·199	−22·4
29	0·3	1·000	.....	+0·370	−·083	+·225	+12·8
31	0·5	1·000	.....	−0·365	−·181	+·221	+10·6
3	0·7	1·000	.....	−0·671	−·123	+·173	− 8·3
12	0·7	1·000	.....	−0·768	−·059	+·147	−12·0
8	0·3	1·000	.....	−0·792	−·041	+·140	−26·5
17	0·5	1·000	.....	−0·840	+·001	+·122	−16·9
34	0·7	1·000	.....	−0·907	+·074	+·088	+10·0
32	0·7	1·000	.....	−0·944	+·236	−·054	−16·9
16	0·7	1·000	.....	−0·928	+·235	−·068	+ 3·2
33	0·7	1·000	.....	−0·780	+·175	−·136	− 6·4
24	0·5	1·000	.....	−0·665	+·110	−·167	−19·9
9	0·5	1·000	.....	−0·378	−·048	−·213	+18·2
22	0·3	1·000	.....	+0·150	−·226	−·231	−27·0
20	0·3	1·000	.....	+0·238	−·234	−·227	−20·3
15	0·7	1·000	.....	+0·674	−·150	−·176	+10·0
25	0·7	1·000	.....	+0·853	−·036	−·129	− 8·4
6	0·7	1·000	.....	+1·026	+·203	+·002	+ 7·4
14	0·7	1·000	.....	+1·010	+·233	+·046	− 1·5
30	0·7	1·000	.....	+1·007	+·235	+·050	− 1·0
23	0·3	1·000	.....	+0·973	+·235	+·079	−28·8
28	0·7	1·000	.....	+0·972	+·234	+·080	+ 2·3
13	0·7	1·000	.....	+0·968	+·234	+·083	−13·6
2	0·7	1·000	.....	+0·922	+·218	+·108	− 2·0

From these were obtained the normal equations:

+35·700u	−2·462w	+1·920x	−0·243y	−0·137z	−51·030 = 0
	+13·613		+0·962	+0·248	+19·717
		+9·879	+0·649	+0·195	+ 9·417
			+0·998	+0·147	− 3·822
				+0·642	+ 1·628

whose solution yields the values:

u	= +1·443	whence	$\delta\gamma$	= +1·44 km.
w	= −1·650		δK_1	= −1·65 km.
x	= −1·656		δK_2	= −1·66 km.
y	= +7·255		δe	= +0·00725
z	= −2·743		$\delta\omega$	= +0·00274
				= 0°·16

The corrected elements together with their probable errors are given in Table VI, while the representations of the observations are shown in Table VII.

The probable error of a single observation of average weight for the primary is ±7·0 km., while for the secondary it is ±8·2 km. The least-squares solution reduced Σpvv by 3·5 per cent.

The velocity of the system was found to be −29·3 km., over 15 km. more positive than that of Adams and Stromberg. This is readily explainable, since a larger eccentricity with periastron in the opposite quadrant would cause the γ axis to be considerably lower. With these exceptions the two sets of elements are in sensible agreement, and we see no occasion to urge a change in the orbital elements during so short an interval.

TABLE VI—THE SPECTROSCOPIC ELEMENTS

Element.	Preliminary	Final	
Period	P = 3·52341	3·52341	±0·00003 days
Eccentricity	e = 0·03	0·037	±0·007
Periastron passage	T = J.D. 2,424,003·703	4003·703	
Periastron minus node primary	ω_1 = 210°	210°·16	±0°·008
Periastron minus node secondary	ω_2 = 30°	30°·16	±0°·008
Velocity of the system	γ = −30·78	−29·34	±1·09 km.
Semi-amplitude primary	K_1 = 220·10	218·45	±1·81 km.
Semi-amplitude secondary	K_2 = 236·25	234·59	±2·11 km.

TABLE VII—REPRESENTATION OF OBSERVATIONS

Observation	Phase from J.D. 2,424,002·0000	Residuals (O–C)			
		Primary		Secondary	
		Prel.	Final	Prel.	Final
33	0·0125	+ 4·7	+ 2·7	+ 2·7	+ 1·8
24	0·1168	− 0·9	− 3·6	+ 3·2	+ 3·0
9	0·3175	−19·1	−21·8	+22·4	+22·3
22	0·6354	+25·7	+22·5	−12·8	−12·4
20	0·6863	+15·6	+12·8	−10·6	−10·6
15	0·9494	− 5·3	− 6·8	+ 8·3	+ 7·0
25	1·1106	−14·8	−15·7	+12·0	+10·1
6	1·4241	− 4·2	− 5·0	+26·5	+24·4
14	1·5232	− 6·8	− 7·2	+16·9	+14·4
30	1·5362	+17·2	+17·5	−10·0	−13·3
23	1·6049	−16·9	−15·1	+16·9	+12·0
28	1·6073	− 1·9	− 0·1	− 3·2	− 8·0
13	1·6097	+ 1·8	+ 3·1	+ 6·4	+ 2·0
2	1·6711	− 3·6	− 2·8	+19·9	+16·1
11	1·7539	+11·0	+10·4	−18·2	−20·5
4	1·9436	− 9·0	−11·7	+27·0	+26·8
1	1·9424	−12·2	−15·0	+20·3	+20·2
29	2·0783	+12·6	+ 9·3	−10·0	− 9·6
31	2·4883	−18·5	−21·3	+ 8·4	+ 8·4
3	2·6915	+ 2·4	+ 0·5	− 7·4	− 8·5
12	2·7761	− 5·8	− 7·5	+ 1·5	+ 0·3
8	2·7986	+ 1·7	0·0	+ 1·0	− 0·2
17	2·8518	+10·7	+ 8·9	+28·8	+27·6
34	2·9451	+11·2	+ 9·4	− 2·3	− 3·5
32	3·3053	+ 3·9	+ 2·1	+13·6	+12·3
16	3·3386	− 6·5	− 8·3	+ 2·0	− 0·9

6. The Calcium Cloud

The mean velocity of calcium has the value $-22{\cdot}43 \pm 0{\cdot}34$ km., but the observations show no variation beyond that due to the accidental error of measurement, as is seen from the velocity curve on page 280. Stellar calcium has not been observed in stars of this type, and the absence of periodic displacement of the lines would certainly exclude a close association of the gas with this rapidly revolving, massive system. We are left, then, with the two possible locations: (1) a local envelope of stellar origin, within the gravitational field of the system, (2) an interstellar cloud of wide distribution. The first hypothesis was preferred by the writer,[5] in the case of *H.D. 216014*, where the velocity of calcium agreed with the velocity of the system. An inspection of the tabular data of Plaskett[6] and Young[7] shows that relatively few systems are satisfied by this explanation. Nevertheless, it is conceivable that such condensations or local envelopes moving with the systems occur. However, for the star under consideration we would consider the second alternative the more probable, and further, the observations indicate a motion of approach of 15 km., as the component of the solar motion is $-7{\cdot}2$ km. This velocity of the drifting cloud is in exact agreement with the weighted mean of the six stars observed by Plaskett[6] in the same region, the Perseus group. At the present time the observations are too few to discuss with certainty the extent and probable motions of such clouds.

7. The Rotational Effect

The rotational effect observed in *β Lyrae*,[8] *Algol*[9] and *21 Cassiopeiae*[10] was not determined from the spectroscopic measures owing to the nebulous nature of the lines. The line-of-sight component would be comparatively small on account of the small maxima obscurations during mid-eclipse, and the low orbital inclination derived in the second section of this paper. Observational differences due to this effect, appreciable in certain phases only, have therefore been distributed along the curve by the least-squares solution.

8. Minimum Masses and Separation

From the elements the projected semi-major axis and the masses were computed as follows:

$$(a_1 + a_2)\sin i = 21{,}935{,}000 \text{ km.} = 31{\cdot}5 \text{ solar radii.}$$
$$m_1 \sin^3 i = 17{\cdot}6\ \odot$$
$$m_2 \sin^3 i = 16{\cdot}4\ \odot$$
$$(m_1 + m_2)\sin^3 i = 34{\cdot}0\ \odot$$
$$\frac{m_1}{m_2} = \frac{K_2}{K_1} = 1{\cdot}07$$

The actual masses will be discussed in Part III after the most probable value of the orbital inclination has been derived from the photometric orbit. We turn now to a consideration of the photometric observations.

REFERENCES TO PART I

[1] Adams and Stromberg.....Contr. Mt. W. Obs., No. 149. Ap. J., *47*, 329, 1918.
[2] O. Struve.....Pop. Ast., *33*, 642, 1925.
[3] Harper and Young.....Pub. D. A. O., *3*, 11, 1924.
[4] H. H. Plaskett.....Pub. D. A. O., *1*, 366, 1921.
[5] J. A. Pearce.....Pub. D. A. O., *3*, 171, 1925.
[6] J. S. Plaskett.....Pub. D. A. O., *2*, 336, 1924.
[7] R. K. Young.....Pub. D. A. O., *1*, 220, 1920.
[8] R. A. Rossiter.....Ap. J., *60*, 15, 1924.
[9] D. B. McLaughlin.....Ap. J., *60*, 22, 1924.
[10] J. S. Plaskett.....Pub. D. A. O., *3*, 247, 1926.

PART II.—THE PHOTOMETRIC ORBIT

1. The Observations

The photometric observations of *H.D. 1337*, $6^m \cdot 22$ P.D., were made by Guthnick[1] during the period 1919 September 10 to 1920 March 1. The comparison stars employed were *P.D. 207*, $5^m \cdot 94$, type A, and *P.D. 129*, $6^m \cdot 15$, type A2. In the course of the investigation the former star was discovered to have a small variation of the order of $0^m \cdot 02$, after the nature of an eclipse, whose period was determined and the effect of this variation upon the measures of *H.D. 1337* eliminated. The spectroscopic orbit of Adams and Stromberg was adopted as a basis, and zero phase taken as J.D. 2,422,212·275 G.M.T. 1919 September 10·275, the predicted time of superior conjunction of the brighter component. The magnitude curve Fig. 2, page 287, represents the observations plotted on the period 3·5225 days.

A subsequent note by Guthnick and Pavel[2] dated 1921 October 29, calls attention to a progression of the phases of the maxima and minima, excepting that of minimum I, which appeared to remain stationary. In consequence of these changes the shape of

TABLE VIII—PHOTOMETRIC PHASES

Epoch	J.D. 2,422,212·275	2,994·270 G.M.T.	Δ P
Phase of m_{II}	0·40	0·65	+0·25
M_{II}	1·28	1·48	+0·20
m_I	2·23	2·23	0·00
M_I	2·95	3·30	+0·35
		Mean	+0·20

the curve is greatly altered, the asymmetrical maximum I showing in 1921 a slow ascent ($P/_3$) and a rapid decline ($P/_4$) quite the reverse of the 1919 curve. No change was found in the range of the light variation, which is of the order of $0^m \cdot 19$. The broad maximum II was observed in 1921 to be more pointed, similar to maximum I, and thus the curve has all the characteristics of a typical *β Lyrae* variation.

The authors made no attempt to solve the photometric orbit, or to represent their observations by theory.

[1] The references are found at the end of the section, p. 295.

2. The Photometric-Spectroscopic Phase Difference

The observed difference of $0^d \cdot 40$ between the photometric and spectroscopic epochs for the eclipse of the brighter star, as well as the increment in the phases of $0^d \cdot 20$ during two years would indicate that the preliminary period of $3^d \cdot 5225$, while satisfactorily representing observations taken over a short interval, was too short. It will be interesting to see how the revised period of $3^d \cdot 52341$ harmonizes the photometric and spectroscopic phases. From the spectroscopic data we compute the predicted times for the eclipses, the transits through the nodes and the epochs of the transverse motion. These are given in Table IX.

TABLE IX—SPECTROSCOPIC-PHOTOMETRIC PHASES

Epoch	Spectro. Phase		Spectro. Phase		Photo. Phase	(O–C)
Sup. Conj. of Br. Star	4002·564	±0·007	2212·672	±0·019	2212·675	+0·003
γ : Fr. star in front	2·546					
$\mho_1$ Br. star	3·425		13·533		13·555	+0·022
Inf. Conj. of Br. star	4·253		14·361		14·505	+0·144
γ : Br. star in front	4·235					
Ω_1 Br. star	5·148		15·256		15·225	−0·031

The computed difference, eclipse $-\gamma$, of $0^d \cdot 018$ is the transverse component of the eccentricity $e \cos \omega = 0 \cdot 032$ radians converted into time. It is only in orbits having ω approximately 90° or 270°, or in circular orbits that this term vanishes and the stars have the velocity of the system at the time of eclipse. In this case the moment of mid-eclipse occurs 26^m later than the time of transverse motion γ. This difference is too small to show graphically in Fig. 1, page 280, where the symbol $\sigma = m$ indicates the coincidence of the computed spectroscopic eclipse and the observed photometric minimum light.

Deducting from the times in column 2, Table IX, the interval 1789·892 days corresponding to the 508 elapsed revolutions, we obtain the predicted times in column 3, which are to be compared with Guthnick's observed times repeated in column 4. The residuals with one exception are satisfactorily small when we consider that the probable error of the predicted phase is $\pm 0^d \cdot 019$. The exception is that of the eclipse of the fainter star, corresponding to m_1, which is very much greater than we would expect, amounting to nearly three and one-half hours. It would seem from the photometric observation, Table VIII, that this is largely due to an error in the determination of m_1, as it is difficult to understand how one phase remains stationary while the others advance at the rate of $0^d \cdot 10$ per year in consequence of an error in the assumed period. It is to be noted that 222 revolutions separate the two photometric epochs, during which time the phases should advance by 0·202 days, as was observed.

The revised period, therefore, satisfies both the spectroscopic and photometric observations. The elements for the prediction of the primary eclipse, that of the brighter star, are: J.D. 2,424,002·564, G.M.T. +3·52341 E ± 0·00003 E. The phase-difference observed by Schlesinger[3] and Plaskett[4] for many eclipsing binaries, and which has recently been explained by the latter[5] as due to observational errors usually in the eccentricity of the spectroscopic orbit, is for this star reasonably explained on that hypothesis.

No change in the photometric curve is effected by plotting Guthnick's observations on the revised period, as the measures were made over a comparatively short interval. The solution of the orbit, therefore, rests upon his published curve.

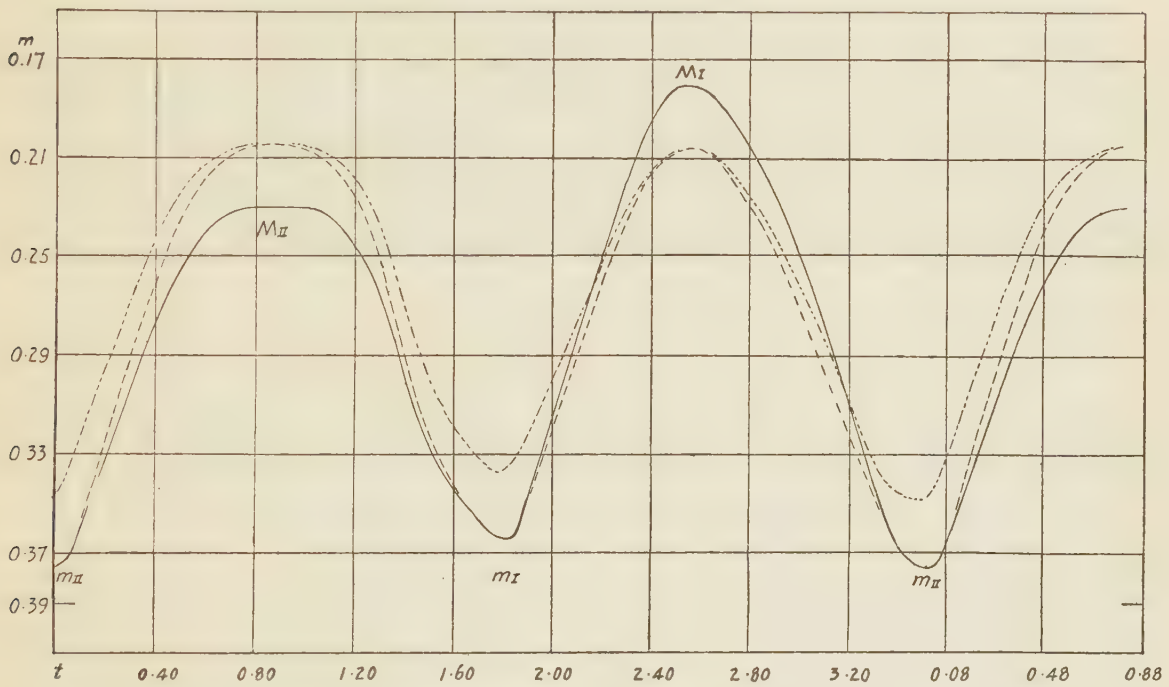

Fig. 2.—Light Curve of H.D. 1337.

————Magnitude curve.....m^{I} (Guthnick) $m_{II} = 0^{d}\cdot00$ $M_{II} - m_{II} = 0^{d}\cdot88$
— — —Rectified for periastron effect.....m^{II} $M_{II} = 0\cdot88$ $m_{I} - M_{II} = 0\cdot95$
— – — –Rectified for periastron and ellipticity effects...m^{III} $m_{I} = 1\cdot83$ $M_{I} - m_{I} = 0\cdot72$
$M_{I} = 2\cdot55$ $m_{II} - M_{I} = 0\cdot97$

3. Interpretation of the Magnitude Curve

The general characteristics of a binary system which gives rise to a *β Lyrae* light curve are so well known that we can deduce from an inspection of the curve certain facts about the physical system. From the absence of a rectilinear portion of the curve at maximum light we observe that the components are not spherical bodies, but have an ellipticity of figure, being elongated due to their mutual attractions, their shortest axes perpendicular to the orbital plane and their longest axes coincident with the line joining their centres. The rounded minima denote that the eclipses are partial and hence point to an inclination differing from 90°. Furthermore, this inclination must necessarily be comparatively small on account of the unusually small range of variation, less than $0^{m}\cdot20$.

The secondary minimum has a well-marked displacement with respect to the epoch ($P/_2$) following the primary eclipse, thus indicating an orbital eccentricity. The small difference in the heights of the rounded maxima point to a periastron effect. Finally, the two bodies have approximately the same surface brightness since the depths of the minima are practically identical.

In order to find the true eclipse elements of the system we have first to remove from the light variations the changes due to the periastron effect and to the ellipticity of figure of the stars.

4. The Periastron Effect

The difference in the observed maxima, of the order of $0^m{\cdot}05$ is here relatively important and must be taken into consideration. It may arise from various causes connected with the eccentricity of the orbit, such as the differential reflection, tidal effects, or increased ellipticity that result when the stars are nearest to each other. The effect may be eliminated by subtracting the term $0{\cdot}025 \sin \theta$ from the observed magnitudes. The broken curve in Figure 2 represents the observations rectified for this variation.

5. Determination of the Ellipticity Constant

The notation used in the remaining sections of Part II is due to Russell[6], whose methods, equations and tables contained in the articles quoted are employed.

From the light curve we pass to the intensity curve by the relation:

$$\log l = 0{\cdot}4\ (m_0 - m) \qquad (1)$$

where unity of light intensity corresponds to maximum magnitude $m_0 = 0{\cdot}205$. For this transformation Russell's[7] table giving the loss of light corresponding to an increase in stellar magnitude is of great use. Plotting the values $1-l^2$ against $\cos^2 \theta$ we obtain a curve whose tangent at the point $\cos^2 \theta = 0$ determines the ellipticity constant z[8]. The derived value is: $z = \tan^{-1} 3°$, $= 0{\cdot}0524$ with an uncertainty of $\pm\ 0{\cdot}05$.

For elliptical stars, darkened at the limb, the factor z_d may be determined in a similar way from the equation:

$$1 - l = z_d \cos^2 \theta \qquad (2)$$

and the uniform factor z_u obtained by the relation[9]:

$$z_u = 5/4\ z_d - (5/28)\ z_d^2 \qquad (3)$$

A plot of $1-l$ against $\cos^2 \theta$ gives the result $z_d = \tan^{-1} 5° = 0{\cdot}0875$, and hence $z_u = 0{\cdot}1080$, a value consistent with the first determination. Two solutions of the orbit will be made, rectifying the observations by the factors $z_1 = 0{\cdot}0524$, and $z_2 = 0{\cdot}1080$.

The values of $1-l^2$ computed from the equation

$$1-l^2 = z \cos^2 \theta \qquad (4)$$

are converted into stellar magnitudes with the help of Table A and the results subtracted from the magnitudes tabulated in column 6, Table X.

An abridgment of the computations is given in Table X, where the several columns have the following significance:

Col. 1, t time intervals from principal minimum in days.
2, θ longitude of the small star measured from inferior conjunction.
3, m^{I} observed magnitude, $6^{m}\cdot00$ +
4, l^{I} light corresponding to m^{I}, $m^{I}_{0} = 0\cdot180$.
5, correction for periastron effect.
6, m^{II} magnitude rectified for periastron variation.
7, l^{II} light corresponding to m^{II}, $m^{II}_{0} = 0\cdot205$.
8, correction for ellipticity factor $z_1 = 0\cdot0524$.
9, m^{III} magnitude rectified for z_1.
10, l^{III} light corresponding to m^{III}.
11, correction for ellipticity factor $z_2 = 0\cdot1080$.
12, m^{IV} magnitude rectified for z_2.
13, l^{IV} light corresponding to m^{IV}.

TABLE X.—ELIMINATION OF PERIASTRON AND ELLIPTICITY VARIATIONS

t	θ	m^{I}	l^{I}	$0\cdot025\sin\theta$	m^{II}	l^{II}	$z_1\cos^2\theta$	m^{III}	l^{III}	$z_2\cos^2\theta$	m^{IV}	l^{IV}
0·0	0·00	0·375	0·8360	0·000	·375	0·8551	·052	·347	0·8774	·108	·313	0·9053
0·2	20·44	0·332	0·8694	+·009	·323	0·8970	·046	·298	0·9179	·095	·268	0·9436
0·4	40·88	0·277	0·9145	+·016	·261	0·9497	·030	·245	0·9638	·062	·226	0·9808
0·6	61·32	0·240	0·9462	+·022	·218	0·9880	·012	·212	0·9936	·025	·204	1·0000
0·8	81·76	0·230	0·9550	+·025	·205	1·0000	·001	·205	1·0000	·002	·204	1·0000
0·9	91·98	0·230	0·9550	+·025	·205	1·0000	·000	·205	1·0000	·000	·205	1·0000
1·0	102·20	0·230	0·9550	+·024	·206	0·9991	·002	·205	1·0000	·005	·203	1·0000
1·2	122·64	0·246	0·9410	+·021	·225	0·9817	·015	·217	0·9889	·031	·207	0·9982
1·4	143·08	0·301	0·8945	+·015	·286	0·9282	·033	·268	0·9436	·069	·248	0·9612
1·6	163·52	0·344	0·8594	+·007	·337	0·8856	·048	·310	0·9078	·099	·280	0·9337
1·8	183·96	0·364	0·8441	−·002	·366	0·8622	·052	·336	0·8864	·108	·304	0·9128
2·0	204·41	0·314	0·8839	−·010	·324	0·8962	·043	·301	0·9154	·090	·273	0·9393
2·2	224·85	0·250	0·9376	−·018	·268	0·9436	·026	·254	0·9558	·054	·238	0·9700
2·4	245·29	0·194	0·9872	−·022	·216	0·9898	·009	·212	0·9937	·019	·206	0·9991
2·6	265·73	0·181	0·9991	−·025	·206	0·9991	·000	·206	1·0000	·001	·206	0·9991
2·8	286·17	0·205	0·9772	−·024	·229	0·9781	·004	·227	0·9799	·008	·224	0·9828
3·0	306·61	0·249	0·9384	−·020	·269	0·9428	·019	·259	0·9515	·038	·248	0·9612
3·2	327·05	0·309	0·8880	−·013	·322	0·8979	·037	·303	0·9137	·076	·279	0·9342
3·4	347·49	0·367	0·8418	−·005	·372	0·8574	·050	·345	0·8790	·103	·313	0·9053
3·52	360·00	0·375	0·8360	0·000	·375	0·8551	·052	·347	0·8774	·108	·313	0·9053

The columns l^{III} and l^{IV} when plotted against the time, give intensity curves whose variations result from the mutual eclipses of the two stars. The solution of these curves gives the desired eclipse elements. The magnitude curve m^{III} is shown in Figure 2 page 287.

6. The Solutions

In the following solutions the stars are regarded as uniformly illuminated discs. This is in accordance with Milne[10], who shows from radiative principles that the limb-centre ratio decreases with increasing temperature, for a given wave-length, and vanishes for high temperature stars. No solution has, therefore, been attempted considering the stars as showing darkening at the limb. The spectroscopic orbit shows that the brighter star is eclipsed at primary minimum. A preliminary solution indicates that the larger star is the brighter.

First Solution—Hypothesis.—Two elliptical stars appearing as uniformly illuminated discs, revolving in a circular orbit, partially eclipse one another. The light curve is rectified for a periastron effect and for an ellipticity factor $z_1 = 0{\cdot}0524$.

From the intensity curve l^{III} we find:

$$\begin{aligned} \lambda_p &= 0{\cdot}8774 \qquad 1-\lambda_p = 0{\cdot}1226 \\ \lambda_s &= 0{\cdot}8864 \qquad 1-\lambda_s = 0{\cdot}1136 \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

From the principal minimum we find values of $\sin^2\theta$ corresponding to different fractions (n) of the maximum obscuration, and deduce the following values of the χ functions:

$$\begin{aligned} \chi\,(k, \alpha_0, 0) &= 2{\cdot}58 \\ \chi\,(k, \alpha_0, \tfrac{1}{4}) &= 1{\cdot}78 \\ \chi\,(k, \alpha_0, \tfrac{3}{4}) &= 0{\cdot}43 \end{aligned}$$

α_0 and k may then be found from the relations:

$$\alpha_0 = 1-\lambda_s + \frac{1-\lambda_p}{k^2} = 0{\cdot}1136 + \frac{0{\cdot}1226}{k^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\frac{c}{D} = \chi\,(k, \alpha_0, \tfrac{1}{4}) = 1{\cdot}78 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

with the help of Table III (Ap. J., *35*, 337).

Using the graphical method described by Russell[11] it is found that the curves representing equations (5) and (6) when superposed in the prescribed manner, run parallel throughout their entire length, thus denoting an indeterminate case. This was indeed expected, for it is well known that the orbits of "eclipsing binaries of such small range . . . . can only be solved by the addition of other data than that derivable from the light curve,"[12]

Passing from a circular to an eccentric orbit, on the same hypothesis, we adopt the spectroscopic values of e and ω. This gives us an additional equation:[13]

$$\frac{1 + kp\,(k\,\alpha_{0p})}{1 + kp\,(k\,\alpha_{0s})} = \frac{1 - e\sin\omega}{1 + e\sin\omega} = 1{\cdot}038 \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

also we have:

$$\frac{1-\lambda_s}{\alpha_{0s}} + \frac{1-\lambda_p}{k^2\alpha_{0p}} = \frac{0.\ 1136}{\alpha_{0s}} + \frac{0.\ 1226}{k^2\alpha_{0p}} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

as the relation between the losses of light and maxima eclipsed areas in an eccentric orbit.[1]

A few trials using Table I (*Ap. J. 35*, 333) for the p- functions, give the values:

$$k = 0{\cdot}65, \qquad \alpha_{0p} = 0{\cdot}395, \qquad \alpha_{0s} = 0{\cdot}430,$$

which satisfy these relations, consistent with the estimated relative intensity of the spectral lines. The beginning of the eclipse takes place at $t' = 0{\cdot}76$, $\theta' = 77° 40'$. The elements i and a are then found from the equations:[15]

$$\left.\begin{aligned} \cos^2 i + \sin^2 i \sin^2 \theta' &= a_1^2 (1-z\cos^2\theta')\ (1+k)^2 \\ \cos^2 i &= a_1^2 (1-z)\left\{1 + kp\ (k, \alpha_{0p})\right\}^2 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

whose solution yields the values: $i = 52° 31'{\cdot}5$, $a_1 = 0{\cdot}598$.

The true elliptical elements are then derived from the circular elements of the primary minimum by means of the approximate equation[16]:

$$\cot i' = \cot i\ (1-2\,g\eta),\ a_1' = a_1\ (1-g\eta) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

They are given in Table XI, together with the remaining elements: ϵ, b_1, a_2, b_2, L_1, L_2, $\frac{J_1}{J_2}$; all of which are readily computed from the simple formulae:

$$\begin{aligned} &\epsilon^2 = z\ \mathrm{cosec}^2\, i, \qquad a_2 = ka_1 \qquad L_1 = \frac{1-\lambda p}{k^2\alpha_{0p}} \qquad L_2 = \frac{1-\lambda_s}{\alpha_{0s}} \\ &b_1^2 = a_1^2\ (1-\epsilon^2) \qquad b_2 = kb_1 \\ &\frac{J_1}{J_2} = \frac{L_1}{L_2}\cdot\frac{r_2^2}{r_1^2} \end{aligned} \quad \ldots\ldots (11)$$

Second Solution.—The solution of the intensity curve I^{IV}, for which $z_2 = 0{\cdot}108$, closely parallels the former solution, which is given in detail above. The different initial conditions are:

$$\left.\begin{aligned} 1-\lambda_p &= 0{\cdot}0950 \\ 1-\lambda_s &= 0{\cdot}0870 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

somewhat smaller, in consequence of the larger value of z. Equation (7) is the same; while the new values of the losses of light (12) are substituted in (8). The resulting elements are tabulated in column 2, Table XI.

TABLE XI—THE PHOTOMETRIC ELEMENTS

Element		Solution		
		I	II	III
Maximum obscuration, primary eclipse	α_{0p}	0·395	0·350	0·480
Maximum obscuration, secondary eclipse	α_{0s}	0·430	0·393	0·514
Ratio of radii	k	0·65	0·59	0·70
Major semi-axis, larger star	a_1	0·607	0·617	$r_1 = 0{\cdot}594$
Minor semi-axis, larger star	b_1	0·581	0·559	
Major semi-axis, smaller star	a_2	0·395	0·364	$r_2 = 0{\cdot}416$
Minor semi-axis, smaller star	b_2	0·377	0·330	
Eccentricity of meridian section	ϵ	0·291	0·425	
Ellipticity constant	z	0·0524	0·1080	
Inclination of orbital plane	i	51°·8	50°·7	56°·0
Light of larger star	L_1	0·736	0·779	0·697
Light of smaller star	L_2	0·264	0·221	0·303
Ratio of surface brightness	$\frac{J_1}{J_2}$	1·175	1·232	

Third Solution—Since any assigned value of the ellipticity, however small, decreases the loss of light at minima and therefore lessens the orbital inclination, a maximum value for this element may be derived by solving the intensity curve l^{I} considering the entire variation as due to the eclipses. The hypothesis of this solution is that of two spherical stars appearing as uniformly illuminated discs and revolving in an elliptic orbit. The losses of light are here:

$$\begin{aligned} 1-\lambda_p &= 0\cdot1640 \\ 1-\lambda_s &= 0\cdot1559 \end{aligned} \qquad \frac{0\cdot1559}{\alpha_{os}} + \frac{0\cdot1640}{k^2\alpha_{op}} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

From the curve we find:

$$\sin^2\theta_{\frac{1}{4}} = 0\cdot7860,\ \sin^2\theta_{\frac{1}{2}} = 0\cdot4636,\ \sin^2\theta_{\frac{3}{4}} = 0\cdot1564.$$

A solution of equations (13) and (7) gives the values:

$$\begin{aligned} k &= 0\cdot70 \qquad L_1 = 0\cdot697 \\ \alpha_{op} &= 0\cdot480 \qquad L_2 = 0\cdot303 \\ \alpha_{os} &= 0\cdot514 \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

The equation defining the beginning of the eclipse

$$\sin^2\theta_o = C\,\omega_2(o) + D\,\omega_1(o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

is here imaginary, indicating that the two stars are in contact. Since we may proceed only be making assumptions, we take the beginning of the eclipse as corresponding to maximum light, for which $t' = 0\cdot93$, $\theta' = 95°\cdot1$. Using equations analogous to (9), in which a_1 is replaced by r, and the term in z is unity, we proceed to the final values given in Table XI.

The third solution, although based on an impossible hypothesis, demonstrates that the inclination cannot exceed the value 56°. The adopted ellipticity factors of solutions I and II are admittedly too low when one considers Darwin's ellipsoids of revolutions[18] and Shapley's results[19]. We would expect such large stars, practically in contact, to exhibit a very large eccentricity of figure; yet the correction of the observed magnitudes by any value of $z > 0\cdot15$ will so distort the intensity curve as to make its interpretation as an eclipse phenomenon very difficult indeed. Considering the spectroscopic confirmation, there is no doubt attending the eclipse hypothesis, and all we can say in regard to the ellipticity is that while the adopted values appear too low, they were derived by the usual method, and appear to satisfy the observations.

7.—Determination of the Dubital Eccentricity

One more comparison remains to be made between the spectroscopic and photometric orbits. From the displacement of the secondary minimum we deduce the transverse component of the eccentricity $e\cos\omega$ by the equation:[20]

$$e\cos\omega = \frac{\pi}{P}\,\frac{(t_2 - t_1 - P/_2)}{(\mathrm{cosec}^2\, i + 1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

Substituting the values: $t_2 - t_1 = m_1 - m_2 = 1\cdot83$ (Table VIII), $i = 51°\cdot8$, $P = 3\cdot52341$, we find for the star being eclipsed at the secondary minimum, i.e., for the fainter star, $e\cos\omega = +0\cdot038$.

Hence for the brighter star $e \cos \omega = -0{\cdot}038$ which is in agreement with the spectroscopic value $-0{\cdot}032 \pm 0{\cdot}007$.

The line of sight component, $e \sin \omega$, is rarely derivable independently from the light curve and then only in the case of a total eclipse, from a consideration of the relative lengths of the minima. We may, however, compute it as a check upon our adopted values of k, α_{op} α_{os} by the relation[21]:

$$e \sin \omega = \frac{(P_s - P_p)\, k}{2 + (P_p + P_s)\, k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Entering Table I (*Ap. J. 35*, 332) we have $e \sin \omega = -0{\cdot}0185$, in exact agreement with the spectroscopic value.

8.—Asymmetry of the Light Curve

The asymmetry of the light curve is usually so small as to escape detection by all but the most refined observations. It is very prominent in this case, as is seen from the intensity curve I^{III}. The effect is to increase the duration of the light changes on that side of the minimum nearest to the adjacent secondary minimum, and to decrease the opposite branch by the same amount ϵ. The computed value [22]is:

$$\epsilon = -h\ (\sec \theta_0 - 1)\ (\mathrm{cosec}^2\, i - \cos \theta_0) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

Substituting the values for light curve I^{III}, $i = 51°{\cdot}8$, t_0 (end of eclipse) $= 0{\cdot}70$, $\theta_0 = 71°{\cdot}5$, $h = -0{\cdot}032$, we deduce $\epsilon = +0{\cdot}089$ radians, which converted into time $= 0.0499$ days. This is in good agreement with the observed value $\epsilon = 0{\cdot}06$ days of I^{III}.

The equations for the orbital eccentricity and the asymmetry of the light curve both involve the inclination of the orbit. The agreement of the former with the observed spectroscopic value, and of the latter with the theoretical amount further strengthens our confidence in the derived value of the inclination.

9. Determination of i and ϵ by Roberts' Theory

Since the masses and the sizes of the stars (and therefore their densities) depend upon an exact determination of the orbital inclination, it is a matter of some consequence to verify the deduced values by an independent method. For this purpose we employ Roberts' theory of a close binary system[23]. In the course of the derivation of the elements, the inclination and the eccentricity of figure are found simultaneously from a consideration of the losses of light at two epochs. Two tables, computed on the basis of stars revolving in contact, are given by the author for determining these elements. Table I (Δm_1) gives the decrease in magnitude at minimum as compared with maximum brightness, computed for every 10° of inclination and every $0{\cdot}1$ of ϵ^2. Table II (Δm_2) gives the decrease in brightness for the same arguments, when the eclipse is half through, when $\theta = 45°$ (Roberts uses ϕ).

For our magnitude curve, m^{II}, corrected only for the periastron effect, we find:

$$\Delta m_1 = 0^m{\cdot}170,\ \Delta m_2 = 0^m{\cdot}050.$$

Interpolating Roberts' tables for these losses of light, we derive the data tabulated in Table XII.

TABLE XII—GRAPHICAL DETERMINATION OF i AND ϵ

For $\Delta m_1 = 0^m \cdot 170$ (Table I)		For $\Delta m_2 = 0^m \cdot 050$ (Table II)	
when $\epsilon^2 = 0 \cdot 0$:	$i = 37° \cdot 0$	when $\epsilon^2 = 0 \cdot 0$:	$i = 35° \cdot 9$
$0 \cdot 1$	$39 \cdot 2$	$0 \cdot 1$	$41 \cdot 4$
$0 \cdot 2$	$41 \cdot 9$	$0 \cdot 2$	$46 \cdot 0$
$0 \cdot 3$	$44 \cdot 6$	$0 \cdot 3$	$50 \cdot 0$
$0 \cdot 4$	$46 \cdot 9$	$0 \cdot 4$	$53 \cdot 5$
$0 \cdot 5$	$49 \cdot 1$	$0 \cdot 5$	$56 \cdot 3$
$0 \cdot 6$	$51 \cdot 4$	$0 \cdot 6$	$58 \cdot 5$
$0 \cdot 7$	$53 \cdot 7$	$0 \cdot 7$	$60 \cdot 7$
$0 \cdot 8$	$55 \cdot 7$	$0 \cdot 8$	$62 \cdot 7$
$0 \cdot 9$	$57 \cdot 4$	$0 \cdot 9$	$64 \cdot 3$

Curves constructed with ϵ^2 and i as coordinates intersect at an angle of 20° at the point $i = 37° \cdot 5$, $\epsilon^2 = 0 \cdot 03$; or since our fundamental plane is the tangent plane, and not that containing the line-of-sight:

$$i = 52° \cdot 5, \ \epsilon^2 = 0 \cdot 03, \ \epsilon = 0 \cdot 174$$

both of which are in excellent agreement with Russell's theory.

10. Conclusion of Part II

The successful application of the eclipse theory to a light variation of such a small amplitude (less than $0^m \cdot 20$) well illustrates the precision of photometric observations made by a skilful observer. Without the assurance that the measures were of the highest order of accuracy it would have been unwise to attempt a solution of a curve whose interpretation is beset with many uncertainties and difficulties. However, the good agreement shown to exist between the photometric and spectroscopic orbits justifies confidence in both sets of observations.

The solution of the orbit principally depends upon the spectroscopic data, in particular upon the estimation of the relative intensity of the spectra. The assumption that the magnitudes of the components are in this ratio has heretofore been made when it is necessary to introduce this ratio in order to effect a solution. The recent investigations on stellar photospheres indicate that this assumption may be greatly in error. But, as Shapley[24] has shown in the case of *u Herculis**, a considerable error in the determination of the magnitude difference does not seriously affect the orbit. A change of k, the ratio of the radii, through a large range is accompanied by small changes in the inclination, masses and densities. This effect is fully considered in the discussion on the absolute dimensions of the components, Part III, page 297.

The confirmation of the orbital inclination and ellipticity factor by the independent method of Roberts strengthens our belief in the accuracy of the deduced values and permits us to confidently proceed with the computation of the absolute dimensions of the system.

* The solution of *H.D. 1337* is similar to that of *u Herculis*.

REFERENCES TO PART II

[1] P. Guthnick: ..... A.N., *5061*, 391, 1920.
[2] P. Guthnick and F. Pavel ..... A.N. *5156*, 395, 1921.
[3] F. Schlesinger ..... Pub. A. O., Volumes 1, 2, 3.
[4] J. S. Plaskett ..... Pub. D.A. O., Volumes 1, 2.
[5] J. S. Plaskett ..... Pub. D. A. O., *3*, 247, 1926.
[6] H. N. Russell ..... Ap. J., *35*, 315; *36*, 54, 1912.
[7] H. N. Russell ..... Ap. J., *35*, 339, 1912.
[8] H. N. Russell ..... Ap. J. *36*, 64, 1912.
[9] H. Shapley ..... Pub. Prin. Obs., *3*, 7, 1915.
[10] E. A. Milne ..... Phil. Trans. A., *223*, 201, 1923.
[11] H. N. Russell ..... Ap. J., *35*, 330, 1912.
[12] H N. Russell ..... Ap. J., *35*, 331, 1912.
[13] H. Shapley ..... Pub Prin. Obs., *3*, 69, 1915.
[14] H. Shapley ..... Pub. Prin. Obs., *3*, 8, 1915.
[15] H N. Russell and H. Shapley ..... Ap. J., *36*, 407, 1912.
[16] H. N. Russell ..... Ap. J., *36*, 57, 1912.
[17] H N. Russell ..... Ap. J. *35*, 329, 1912.
[18] G. Darwin ..... Phil Trans. A., *206*, 160, 1906.
[19] H. Shapley ..... Pub. Prin. Obs., *3*, 115, 1915.
[20] H. N. Russell ..... Ap. J. *36*, 57, 1912.
[21] H. N. Russell ..... Ap. J. *36*, 58, 1912.
[22] H. N. Russell ..... Ap. J. *36*, 59, 1912.
[23] A. W. Roberts ..... M.N., *63*, 535, 1903.
[24] H. Shapley ..... Pub. Prin. Obs. *3*, 70, 1915.

PART III.—THE PHYSICAL CHARACTERISTICS OF THE SYSTEM

1. Constants and Derived Elements

The computations in Part III are based upon the following constants for the sun and the elements determined in the preceding parts of the paper.

Sun $\quad T = 5860° \quad m = -26^m\cdot72 \quad M = +4^m\cdot85$
$\quad d = 1920'' \quad D = 865{,}000$ mls. $\quad R = [5\cdot84264]$ km.

H.D. 1337	Spectroscopic Data	Photometric Data	
$m_1 \sin^3 i$	$= 17\cdot6\ \odot$	$i = 51°\cdot8 \pm 1°\cdot1$	
$m_2 \sin^3 i$	$= 16\cdot4\ \odot$	$r_1 = 0\cdot594\ a$	$L_1 = 0\cdot736$
$a \sin i$	$= 21\cdot935{,}000$ km.	$r_2 = 0\cdot386\ a$	$L_2 = 0\cdot264$
	$= 31\cdot5$ solar radii		

2. Absolute Masses and Dimensions

Combining the results of the two orbits, the actual masses and dimensions of the two stars are readily computed.

Separation $a = 27{,}918{,}000 \pm 429{,}000$ km.
$\quad = 40\cdot1 \pm 0\cdot6$ solar radii

	Brighter component		Fainter Component	
Mass	$36\cdot3$	$\pm 1\cdot7\ \odot$	$33\cdot8$	$\pm 1\cdot6\ \odot$
Radius	$23\cdot8$	$\odot$	$15\cdot5$	$\odot$
Surface	$566\cdot4$	$\odot$	$240\cdot2$	$\odot$
Volume	13480	$\odot$	3723	$\odot$
Density	$0\cdot0027$	$\odot$	$0\cdot0091$	$\odot$

The 6 per cent uncertainty in the masses results from the 2 per cent uncertainty in the orbital inclination.

The densities may be checked by the formula of Russell[1]:

$$\rho_1 = 0\cdot01344 \frac{y}{p^2 r_1^3} \qquad \rho_2 = 0\cdot01344 \frac{1-y}{p_2 r_2^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (19)$$

by substituting the minimum masses found in part I: $y = 0\cdot518$, $1-y = 0\cdot482$ and the relative radii deduced in part II:

$$r_1 = 0\cdot594 \qquad r_2 = 0\cdot386$$

Undoubtedly the most important result of this investigation is the determination of the densities of these O-type stars. It is necessary, therefore, to carefully consider the effect on the densities of a considerable error in the principal assumption of Part II, namely, that the stars differ by $1\cdot11$ magnitudes. To show that the physical properties of the system, i.e., the size of the orbit, the inclination of the orbital plane, the radii,

[1] The references are found at the end of the section, page 306.

masses and densities of the component stars are little changed, even when the magnitude difference varies through a considerable range, we make three additional solutions of the photometric orbit, adopting values of Δm varying from $0^m \cdot 25$ to $1^m \cdot 11$. The results are given in Table XIII.

TABLE XIII—CONDITIONAL SYSTEMS

Element	I	II	III	IV
	m	m	m	m
Δm	0·25	0·50	0·80	1·11
L_1	0·557	0·613	0·676	0·736
L_2	0·443	0·387	0·324	0·264
$K = \frac{r_2}{r_1}$ ...	0·97	0·86	0·74	0·65
α_{op}	0·234	0·270	0·320	0·395
α_{os}	0·257	0·294	0·351	0·430
i	50° 01′·5	50° 33′·5	50° 43′·0	51° 47′
a_1	0·508	0·538	0·575	0·607
b_1	0·485	0·514	0·549	0·581
a_2	0·493	0·462	0·426	0·395
b_2	0·470	0·442	0·406	0·377
r_1	0·496	0·526	0·562	0·594
r_2	0·481	0·452	0·416	0·386
$r_1 + r_2$....	0·977	0·978	0·978	0·980
a	41·1 ⊙	40·8 ⊙	40·7 ⊙	40·1 ⊙
m_1	39·1 ⊙	38·2 ⊙	37·9 ⊙	36·3 ⊙
m_2	36·4 ⊙	35·5 ⊙	35·3 ⊙	33·8 ⊙
ρ_1	0·0046 ⊙	0·0038 ⊙	0·0032 ⊙	0·0027 ⊙
ρ_2	0·0047 ⊙	0·0057 ⊙	0·0073 ⊙	0·0091 ⊙

The results of Table XIII are quite satisfactory. As the components change from a condition of equality (system I) to one in which the primary star is fifty per cent larger than the secondary star (system IV) the accompanying changes in the elements are in general small. The density varies the most, but even in this case the order is not changed. Any of the systems would satisfy the photometric observations. In conformity with the general practice of previous investigators, the fourth system is adopted, although the assumption involved is questionable, and the possibility of the other solutions admitted.

The mass of the binary system is exceeded by two other spectroscopic double stars, *B.D. 6°·1309* and *29 C. Ma.* It is, however, the most massive of the eclipsing systems thus far determined, the next in order being *V Puppis* (37·2 ⊙) and *Y Cygni* (31·9 ⊙).

3. The Masses of the O-Type Stars

From a discussion of the four O-type orbits available in 1924, Plaskett[2] reached the conclusion that the average mass of these stars is at least five times that of the B's, and is of the order of 40–50 times the solar mass. This estimate is supported by our knowledge of the masses of planetary nebulae, the nuclei of which are either Wolf-Rayet or absorption O-type stars.

Since the publication of his memoir, information on the masses of three additional systems is available. Two of these, *Y Cygni* and *H.D. 1337*, are eclipsing variables

whose actual masses are known, and two of the remaining five are double-lined binaries, so that we know their minimum masses. A computation after the usual manner of assigning the probable ratios, $\frac{m_2}{m_1} = 0{\cdot}7$, and $\frac{m_2}{m_1} = 0{\cdot}5$, to the three single-lined systems, and adopting the average inclination for the five orbits for which this information is lacking, shows that the average mass lies within the limits of 38·5 and 51·5 times the solar mass. This result, for the brighter stars of these seven systems, corroborates the earlier conclusion that the mass of the average O-type star is of the order 40–50 times the sun's mass.

It is interesting. also, to discuss the subject after the method of Struve[3]. In his paper, Struve combines the O's and B's into one class and subdivides the stars into fifteen small groups whose average periods range from 0·709 to 885^d·8. In the following treatment, the O's will be considered separately, Cepheids, pseudo-Cepheids and doubtful stars excluded, and the ordinary divisions of spectral sub-classes retained. The results cannot well be compared. The unusual mass of the O-type stars is readily perceived when we compare the class with the B stars, particularly with the three following spectral subdivisions, the early B's. In their physical properties of mass and temperature and in their spectral characteristics the stars of types B0, B1 and B2 are more closely related to the O's than to the later subdivisions of class B. The mass data for these, the most massive of binary systems, are given in Table XIV, the information being taken from the *Third Catalogue of Spectroscopic Binaries* supplemented by recently published investigations.

TABLE XIV—MASS DATA FOR O, B0, B1 AND B2 BINARIES

Star	Type	log 10P	K	$\frac{m_2^3 \sin^3 i}{(m_1+m_2)^2}$	$m_1 \sin^3 i$	$m_2 \sin^3 i$	m_1	m_2	$\frac{m_2}{m_1}$	C
B.D. 44°·3639	O6n	2·69	42	0·374	.....	.....	.....	.....	.....	153·3
29 C. Ma.	O7e	1·64	218	4·58	.....	.....	.....	.....	.....	357·0
ι Ori.	O8	2·46	110	1·14	.....	.....	.....	.....	.....	338·5
B.D. 6°·1309	O8e	2·16	206	.....	75·6	63·3	.....	.....	0·84	501·3
H.D. 1337	O8·5n	1·55	218	.....	.....	.....	36·3	33·8	0·93	358·2
H.D. 191201	O9n	1·92	157	.....	13·9	12·9	.....	.....	0·93	318·3
Y Cyg.	O9·5n	1·48	224	.....	.....	.....	16·6	15·3	0·92	322·9
H.D. 216014	B0n	1·36	225	.....	14·2	12·4	.....	.....	0·87	296·5
Boss 6142	B0n	2·13	116	.....	18·5	12·7	.....	.....	0·69	275·8
β Sco.	B0n	1·83	126	.....	13·0	8·3	.....	.....	0·64	239·0
*V Pup.	B1p	1·16	313	.....	.....	.....	19·2	17·9	0·93	354·6
η Ori.	B1s	1·90	145	.....	11·2	10·6	.....	.....	0·95	289·9
θ^2 Ori.	B1n	2·32	94	1·795	.....	.....	.....	.....	.....	259·5
δ Ori.	B1n	1·76	101	0·589	.....	.....	.....	.....	.....	180·8
o Per.	B1	1·65	112	.....	5·42	3·79	.....	.....	0·70	183·7
ψ Ori.	B2n	1·40	144	.....	5·53	4·19	.....	.....	0·76	196·1
ν Ori.	B2	3·12	34	0·277	.....	.....	.....	.....	.....	172·8
.....	B2	1·60	126	.....	9·6	5·8	.....	.....	0·60	200·2
Boss 5070	B2	2·09	120	1·02	.....	.....	.....	.....	.....	280·3
‡ ξ^2 Cen.	B2	1·90	140	.....	.....	.....	.....	.....	.....	243·1

* Relative orbit: $K_1+K_2 = 604$ km., largest known.
$(m_1+m_2) \sin^3 i = 33$ ⊙
Shapley's darkened solution gives cos $i = 0{\cdot}247$, and hence
$m_1 = 19{\cdot}2$ ⊙, $m_2 = 17{\cdot}9$ ⊙, $K_1 = 313$ km., $K_2 = 291$ km.

‡ Relative orbit: $K_1 + K_2 = 312$ km.
$(m_1+ m_2) \sin^3 i = 16{\cdot}4$ ⊙
For $\frac{m_2}{m_1} = 0{\cdot}81$, $K_1 = 140$ km., $K_2 = 172$ km.

The following stars have been omitted from the discussion, as their binary nature is questionable.

Star	Type	K	Mass Function	Remarks
B.D. 56°·2617	O6n	77	0·054	Probably pseudo-Cepheid.
ξ Per.	O7	8	0·00035	Orbit from H and K lines of calcium.
9 Cam.	O9	9	0·0023	Orbit from H and K lines of calcium.
ψ Per.	B0p	27	0·1888	Small K.
χ Aur.	B1	21	0·56	Orbit from H and K lines of calcium. Period, 655·16 days.
β C. Ma.	B1s	9	0·00002	Pseudo-Cepheid.
σ Sco.	B1	39	0·00176	Pseudo-Cepheid.
β Ceph.	B1s	17	0·000095	Cepheid variable.
12 Lac.	B2s	17	0·0001	Pseudo-Cepheid.
ν Cen.	B2	21	0·00239	Probably pseudo-Cepheid.

The columns of Table XIV are self-explanatory with the exception of the last one, where C is the mass constant occurring in the Keplerian expression $K^3 P = C^3$. The stars may be located on Struve's[4] interesting diagram by using the third and fourth columns as coordinates.

It is very apparent from the last column of Table XIII that the average value of C decreases throughout the four spectral subdivisions. Taking the means, the corresponding masses are computed by the equation:

$$* \log mass_{av} = 3 \log C_{av} + [4{\cdot}26005] \quad \ldots\ldots (20)$$

we find:

TABLE XV—AVERAGE MASSES OF O- AND B-TYPE BINARIES

No.	Type	Average C	Average M (Total Mass)	Average m (Brighter component)
7	O	335·9	69·0 ⊙	38·3 ⊙
3	B0	270·4	36·0	20·0
5	B1	253·7	29·7	16·5
5	B2	225·5	20·9	11·6
22	B3	121·8	3·3	1·8
† 9	B5	97·2	1·7	0·9
‡10	B8	148·4	5·9	3·3
§ 4	B9	116·6	2·9	1·6
¶ SUMMARY				
7	O	.....	69·0 ⊙	38·3 ⊙
13	B0–B2	.....	27·8	15·4
45	B3–B9	.....	3·3	1·8
58	B0–B9	.....	8·8	4·9

* This equation is derived by substituting the values $K_2 = 1.25\ K_1$, $e = 0$, $\sin^3 i_{av} = 0.65$, in the well-known formula for binary stars.

† Omitting ν *Gem.*, period $9^{y}{\cdot}6$, mass > 170 ⊙.

‡ Including β *Lyrae* and μ *Sgr.*, excluding τ Sgr.—composite spectrum.

§ Excluding *TV Cass.*—spectral type A0.

¶ Note added April 12th.—Struve's recent paper, *A.N.* 5432, 13, 1926, received to-day, gives the mass of the average O and B star as 19 ⊙. This is higher than the average value of the above table (15·3 ⊙) in consequence of his use of the ratio $\frac{m_2}{m_1} = 0{\cdot}5$, instead of the usual value $\frac{m_2}{m_1} = 0{\cdot}7$.

The dispersion in mass as we proceed from the O's through the subdivisions of the B's is very evident, and this a strong argument for treating the O-type stars separately from the B-type stars in any statistical discussion on the masses, notwithstanding the small number of systems available. Further, this comparative method brings out clearly the great difference in mass between the early and late class B stars. The stars of the earlier divisions in this respect are as closely related to the O's as those of the latter division are to the A's, and the gap between B2 and B3 is considerably greater than we have heretofore supposed. Indeed, there is as great a mass difference between the early and late class B stars as between the average class O and class B stars, the former being seven times more massive than the latter.

By this method also the average O- class star is shown to be approximately forty times as massive as the sun.

4. The Density of the O-Type Stars

The densities of the component stars of *H.D. 1337* have been shown to be 0·003 Do for the large primary, and 0·009 Do for the smaller secondary. We know the densities of only one other O-type binary, namely *Y Cygni* O9·5n*, for whose components the values 0·170 Do and 0·158 Do have been determined. We thus have the interesting fact that a considerable dispersion in density, approximately 100-fold, occurs in this group of high temperature stars, even indeed between two stars of the same spectral type and temperature. Apparently these systems must be in different stages of evolution, and if we may use the terms giant and dwarf for stars of this class, *Y Cygni* is a dwarf eclipsing system, since the similar components are spherical in form, of diameter 4·6 times the sun and separated by a distance of 28 solar radii. That is, the adjacent surfaces of these stars are not closer than one-thirteenth of an astronomical unit. In contrast to this, *H.D. 1337* is a giant system, probably of comparatively recent formation, whose ellipsoidal components have the unusual size of 24 and 15 solar diameters, and they revolve practically in contact.

But it seems obvious from several considerations that the density of *Y Cygni* must be considerably higher than the average O star, and in all probability *H.D. 1337* represents the other extreme. In attempting to assign a mean density we may be guided by the data from the B-type eclipsing binaries. Excluding the abnormal systems *β Lyrae* and *RS Vulpeculae*, the average density of the remaining five is 0·087, for the ten components† the values ranging from 0·015 to 0·180. It is very reasonable to expect a somewhat lower density for the O's, when we take into consideration the increased radiation pressure in the atmosphere of these more massive stars. For these reasons, and in conformity with Seare's values of the mean densities of the B's, estimates varying from 0·1 Do to 0·01 Do have been given to the different O- and B-type stars whose spectroscopic orbits have recently been completed at this institution. The establishing of the low densities of *H.D. 1337* not only emphasizes the conservativeness of these assumptions, but shows that the lower limit must be extended to 0·001 Do.

* The spectrum has recently been re-examined. When the spectra of the two components are superposed, faint O-type lines of ionized helium and ionized nitrogen are discernible.

† For the brighter components only the average density is 0·12 Do.

To conclude this section we may say that the less massive and less luminous O's have densities varying from 0·1 to 0·01 Do with a mean of 0·05 Do. The more massive stars, such as *B.D. 6°·1309, 29 C. Ma.* and those having absolute magnitudes greater than $-4^{m}\cdot0$, have densities probably ranging from 0·01 to 0·001 Do, with a mean of 0·005 Do. The mean value 0·01 Do for this class O, preferred by Plaskett,[5] is verified by this investigation.

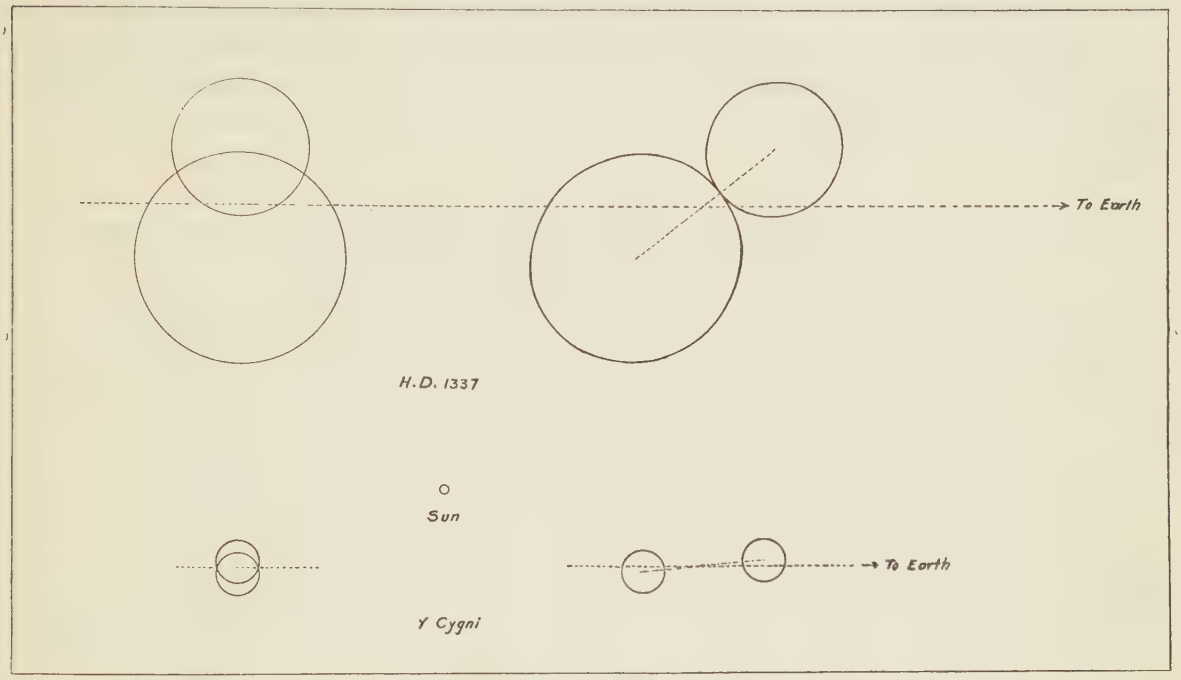

Fig. 3.—Relative Dimensions of H.D. 1337, Y Cygni and the Sun.

5. The Apparent and Absolute Magnitudes

The light ratio of the two stars indicates a difference of 1·11 in their apparent magnitudes. Seen separately the stars would have the apparent magnitudes of 6·56 and 7·67. Their combined brightness is 6·22 on the Potsdam system. It is given as 6·12 in the *Henry Draper Catalogue.*

The most direct way of computing the absolute magnitude of an eclipsing binary is by the luminosity method, as the size of the star is known and the surface brightness may be inferred from the spectral type. Accepting Fowler and Milne's[6] temperature scale, we would assign a temperature of 28,000° K to an O8·5 star. The corresponding surface brightness computed by Hertzprung's[7] formula is $j_{H} = -3^{m}\cdot92$, thirty-seven times brighter than the sun per unit area. This gives for the brighter star $M_{v} = -5^{m}\cdot95$ and applying the correction $M_{v} - M_{B}$[8] $= +2^{m}\cdot87$ to reduce the magnitude to the bolometric scale, we have: $M_{B} = -8^{m}\cdot82$. For the secondary star:

$$\frac{J_1}{J_2} = 1\cdot175,\ J_2 = -3^{m}\cdot75,\ M_{v} = -4^{m}\cdot84,\ M_{v} - M_{B} = +2\cdot47,\ M_{B} = -7^{m}\cdot31.$$

The bolometric absolute magnitude may be checked by the formula given by Eddington[9]:

$$M_B = 4{\cdot}85 - 5 \log r/r_s - 10 \log T/T_s \quad \ldots\ldots (21)$$

A final check upon the values of the mass, density, absolute magnitude and surface brightness may be obtained by computing the density from the relation which holds between these constants of a star[10]:

$$\log \rho = \log mass + 0{\cdot}6\,(m_v - j) - 2{\cdot}91^* \quad \ldots\ldots (22)$$

Recently, the visual absolute magnitude (M_v) of the brighter components of a number of O- and B-type binaries investigated here, have been computed by the luminosity method. For convenience the temperatures at present adopted and the corresponding values of the surface brightnesses and magnitude differences are given in Table XVI.

TABLE XVI—TEMPERATURE (T), SURFACE BRIGHTNESSES (j) AND MAGNITUDE DIFFERENCES ($M_v - M_B$) FOR O- AND B-TYPE STARS

Type	T	j_H	$M_v - M_B$
		m	m
O5	35000° K	−4·15	+3·61
O6	33000	−4·10	+3·41
O7	31000	−4·03	+3·20
O8	29000	−3·96	+2·98
O9	27000	−3·88	+2·76
B0	25000	−3·78	+2·52
B1	22000	−3·61	+2·13
B2	19000	−3·38	+1·73
B3	16000	−3·08	+1·28
B5	14000	−2·80	+0·98
B8	12500	−2·54	+0·75
B9	11500	−2·33	+0·60
A0	10000	−1·94	+0·38

The temperature is an interpolation of Fowler and Milne's[6] scale, assuming a uniform difference of 2000° between the O-type subdivisions; a uniform difference of 3000° between the early subdivisions of class B. The surface brightnesses are computed by Hertzsprung's[7] formula, assuming that it holds at the higher temperatures:

$$j_H = +2{\cdot}3 \left(\frac{14300}{T}\right)^{0{\cdot}93} - 5{\cdot}15\dagger \quad \ldots\ldots (23)$$

The magnitude difference which is given by Eddington[12] and Seares[11] for temperatures up to 12000° is computed by the formula:

$$M_v - M_B = j_H + 10 \log T - 37{\cdot}68 \quad \ldots\ldots (24)$$

Bolometric absolute magnitudes computed by these formulae are in exact agreement with those computed by Eddington's formula (21).

* When water is taken as the unit of density the constant in this equation is −2·77. In this paper the densities are referred to the sun.

† The constant −5·15 in this equation was obtained from the tabular data given by Seares.[11]

It is interesting to note that Eddington's Mass-Luminosity theory does not satisfactorily predict the absolute magnitudes of the components of this stsyem. The stars are outside the region shown by his graph. Deducing the bolometric absolute magnitude differentially from *Capella* by means of the tabular data we obtain the values of $-6^m\cdot54$ and $-6^m.28$, which, when compared with the observed bolometric magnitudes, give residuals of $-2^m\cdot28$ and $-1^m\cdot03$. That is, the theory appears to give too small a magnitude to these massive high-temperature and tenuous stars.

That the denser stars are well represented is evident from the smallness of the residuals. The agreement is even better than given by Eddington. Making the following changes in spectral type,

Y Cygni	B2 to O9·5
U Oph.	B9 to B5
RS Vulp.	A0 to B5
U Cor.	B3 to B8

and adopting Fowler and Milne's temperature scale, a recomputation for the thirteen eclipsing variables considered reduces the average residual from $\pm0^m\cdot56$ to $\pm0^m\cdot41$.

The secondary stars were not considered by Eddington as the information in regard to them is generally not as trustworthy as for the primary stars. The exact spectral type of the fainter component cannot always be definitely established, although it is usually stated that the two stars have identical spectra. Upon this assumption, a similar computation gives the average residual for the fainter components of eleven systems (*β Lyrae* and *RS Vulpeculae* excluded) as $\pm1^m\cdot70$. The stars are arranged in Table XVII in the order of increasing density.

TABLE XVII—MASS, DENSITY, ABSOLUTE MAGNITUDE DATA OF ECLIPSING VARIABLES

Primary Stars	Type	Temperature	Mass	Density	M_B	M_C	(O–C)
		°			m	m	m
H.D. 1337	O8·5	28,000	36·3 ⊙	0·003 Do	−8·82	−6·54	−2·28
V Pup	B1	22,000	19·2	0·046	−5·26	−5·12	−0·14
Z Vulp	B3	16,000	5·24	0·085	−2·64	−1·91	−0·73
u Herc	B3	16,000	7·5	0·097	−2·66	−2·81	+0·15
β Aur	A0p	10,500	2·39	0·109	+0·08	+0·76	−0·68
TV Cas	A0	10,000	1·83	0·118	+1·56	+1·72	−0·16
Y Cyg	O9·5	26,000	16·6	0·170	−4·94	−4·96	+0·02
U Cor	B8	12,500	4·27	0·175	−0·75	−1·16	+0·41
U Oph	B5	14,000	5·36	0·18	−1·37	−1·85	+0·48
Z Herc	F2	7,600	1·6	0·29	+2·48	+2·60	−0·12
TX Herc	A2	9,800	2·04	0·87	+2·00	+1·35	+0·65
W U. Ma	F8p	6,200	0·74	2·8	+5·37	+5·81	−0·44

TABLE XVII—MASS, DENSITY, ABSOLUTE MAGNITUDE DATA OF ECLIPSING VARIABLES—Concluded

Secondary Stars	Type	Temperature	Mass	Density	M_B	M_C	(O–C)
		°			m	m	m
H.D. 1337	O8·5	28,000	33·8 ⊙	0·009 Do	−7·31	−6·28	−1·03
U Cor	B8	12,500	1·63	0·015	−1·82	+1·96	−3·78
u Herc	B3	16,000	2·9	0·023	−3·01	−0·24	−2·77
Z Vulp	B3	16,000	2·36	0·033	−2·61	+0·43	−3·04
Z Herc	F2	7,600	1·3	0·04	+1·13	+3·14	−2·01
TV Cas	A0	10,000	1·01	0·044	+0·27	+4·05	−3·78
V Pup	B1	22,000	17·9	0·057	−5·05	−4·97	−0·08
β Aur	A0p	10,500	2·35	0·107	+0·08	+0·81	−0·73
Y Cyg	O9·5	26,000	15·3	0·158	−4·94	−4·81	−0·13
U Oph	B5	14,000	4·71	0·16	−1·37	−1·52	+0·15
TX Herc	A2	9,800	1·77	0·75	+2·00	+1·86	+0·14
W U. Ma	F8p	6,200	0·52	1·9	+5·37	+7·41	−2·04

M_B is the bolometric absolute magnitude computed by the luminosity method.
M_C is the bolometric absolute magnitude computed by Eddington's theory.

Satisfactory results are obtained for such systems as *Y Cygni* and *V Puppis*, where the components have approximately the same mass and are of equal density. But such systems as *Z Vulpeculae*, *u Herculis*, *U Coronae*, etc., where the more massive and denser primary is attended by a larger and less dense secondary evidently present difficulties. If peculiar radiating conditions exist so that the observed spectra greatly mislead us as to the true effective temperatures of the secondaries, then, as Eddington[13] states, "It is a failure of the test rather than of the theory." However, the progression noted in the residuals seems to indicate that Eddington's theory applies to stars which have reached a certain order of density and that in the earlier stages of evolution, such as apparently present in *H.D. 1337*, possibly rather an exceptional condition, some correction to the theory is required.

6. The Parallax and Space Velocity

The parallax computed by the usual formula from the visual absolute magnitude is $\pi = 0''\cdot00032$, a distance of 3200 parsecs, approximately 10,000 L.Y. This star, and *B.D. 6°·1309*, which has the same hypothetical parallax, are at variance with Wilson's[14] view, that the O-type stars are situated in a ring of radius 2500 L.Y., $\pi = 0''\cdot0013$. According to Boss, the total proper motion is $0''\cdot0096$ annually, after applying the proposed corrections to the proper motions in right ascension and declination. This observed proper motion represents a linear tangential velocity of 143 km. per second and when combined with the observed radial velocity gives a space velocity of 146 km. per second for the system.* This high space velocity for such a massive binary makes the system more interesting. It is in accordance with Plaskett's[15] result that the average space velocity of the faster-moving O-type stars is 94 km. per second.

* The parallax, tangential and space velocities are reduced twenty per cent if we adopt a temperature of 20,000° rather than 28,000° for this star.

7. Comparison Between *B.D. 6°·1309* and *H.D. 1337*

In concluding this discussion on the physical characteristics of the system it is interesting, but probably not otherwise significant, to call attention to the many singular coincidences between the elements of the binary systems *B.D. 6°·1309*, the most massive system known, and *H.D. 1337*. The comparison is made in Table XVIII.

TABLE XVIII—SIMILARITY OF ELEMENTS

Star		B.D. 6°·1309	H.D. 1337
Spectral Type		O8e	O8·5
Temperature	T	28,000°	28,000°K
Period	P	14·414	3·52341 days
Eccentricity	e	0·035	0·037
Amplitude	$K_1 + K_2$	453·08	453·04 km.
Periastron minus node	ω_1	181°·95	210°·16
Separation	$a \sin i$	129	31·5 solar radii
Mass	$M \sin^3 i$	138·9	34·0 ⊙
Density	ρ	(0·01)	0·0027, 0·0091 Do
Visual magnitude	m	6·12	6·12
Abs. mag. vis.	M_V	−6·3	−6·3
Abs. mag. bol.	M_B	−9·1	−9·1
Parallax	π	0″·00035	0″·00032
Total proper motion	μ	0″·0114	0″·0114, uncorrected 0″·0096, corrected
Radial velocity	V_0	+ 24	−29 km. p.s.
Tangential velocity		154	143 km. p.s.
Space velocity		156	146 km. p.s.

If the period of *H.D. 1337* were four times as long the two systems would be practically identical in all respects. This remarkable resemblance does not appear to have a parallel in the catalogue of spectroscopic binaries.

8. Summary

The absolute dimensions of the O-type eclipsing binary *H.D. 1337* have been determined. Twenty-six observations of the radial velocities of both components form the basis of the spectroscopic investigation. The very accurate photometric measures of Guthnick indicated a light variation of the *β Lyrae* type of unusually small amplitude, less than $0^m \cdot 19$. The measures were corrected for the periastron and ellipticity effects peculiar to these systems, and the resulting eclipse curve solved by introducing data from the spectroscopic orbit. The photometric orbit alone, is indeterminate. The elements common to the two orbits agree within the errors of observation. The system consists of two giant O-type stars, of linear sizes 23·8 and 15·5; of masses 36·3 and 33·8; and of densities 0·003 and 0·009 compared with our sun. These stars revolve practically in contact in a slightly elliptical orbit whose plane is inclined at the angle of 38° to the plane containing the line of sight. The period is 3·52341 days. Their exceedingly high temperatures, 28,000° K, and consequent high surface brightnesses when combined with their enormous sizes, place the stars among the most luminous thus far determined, the components having visual absolute magnitudes of $-5^m \cdot 94$ and $-4^m \cdot 83$.

On the bolometric scale their magnitudes are $-8^m\cdot81$ and $-7^m\cdot30$. The deduced parallax is $0''\cdot00032$, a distance of approximately 10,000 light years. The observed total proper motion of $0''\cdot0096$ annually and radial velocity of -29 km. per second give a space velocity of 146 km. per second for the centre of gravity of the system.

Through the work of Roberts[16], Myers[17], Curtiss[18], Shapley[19] and others we are familiar with such eclipsing systems in the well-known stars *β Lyrae*, *V Puppis*, *RR Centauri*, etc. According to Jeans[20] interesting theory of the Evolution of Binary Stars it would appear from the observed spectral type and density that we have here one of the youngest members of this large family, the fission having recently taken place, if, indeed, it is completed.

The two O-class representatives of eclipsing binaries, *Y Cygni* and *H.D. 1337*, have been shown to differ greatly in their physical characteristics, the former being a typical dwarf binary and the latter a giant system. It is hoped that these two will not long remain the only O-type systems whose absolute dimensions are known, as it is here in this small class of very massive high-temperature stars that information is urgently required in order to stabilize the current theories of stellar evolution.

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March, 1926.

REFERENCES TO PART III

[1] H. N. Russell.....Ap. J., *36*, 73, 1912.
[2] J. S. Plaskett.....Pub. D. A. O., *2*, 298, 1924.
[3] O. Struve.....M.N., *86*, 63, 1925.
[4] O. Struve.....M.N., *86*, 70, 1925.
[5] J. S. Plaskett.....Seelinger Festschrift, p. 333, 1924.
[6] Fowler and Milne.....M.N., *84*, 505, 1924.
[7] E. Hertzsprung.....Zeitschrift für Wissenschaftliche Photographie, *4*, 43. 1906
[8] F. Seares.....Cont. Mt. W. Obs., *10*, 398, 1921.
[9] A. S. Eddington.....M.N., *84*, 317, 1924.
[10] F. Seares.....Contr. Mt. W. Obs., *10*, 402, 1921.
[11] F. Seares.....Contr. Mt. W. Obs., *10*, 399, 1921.
[12] A. S. Eddington.....M.N., *77*, 605, 1917.
[13] A. S. Eddington.....M.N., *84*, 319, 1924.
[14] R. E. Wilson.....Ap. J., *36*, 1, 1924.
[15] J. S. Plaskett.....Pub. D. A. O., *2*, 333, 1924.
[16] A. W. Roberts.....M.N., *63*, 527; 1903, *66*, 123, 1906.
[17] G. W. Myers.....Ap. J., *7*, 1, 1898.
[18] R. H. Curtiss.....Pub. A. O., *2*, 73, 1911.
[19] H. Shapley.....Pub. Prin. Obs., *3*, 72, 1915.
[20] J. H. Jeans.....M.N., *85*, 797, 1925.

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THE ORBITS OF TWO SPECTROSCOPIC BINARIES

By W. H. Christie

ABSTRACTS

H. R. 6506.—Thirty-five spectrograms of the star H.R. 6506 (H.D. 158261) form the basis of the determination of the orbit of this spectroscopic binary. As determined from our spectrograms the type is A2, although given in the H.R. and H.D. catalogues as B9. The spectrum is characterized by sharp lines suitable for accurate measurement. The period, determined graphically, is 5·9182 days, the eccentricity is ·031. The probable error of a single plate is ±1·5 km. per second.

H. R. 5752.—The orbital elements of the spectroscopic binary H.R. 5752 have been determined from measures of forty-one single-prism spectrograms. The period is 1·0085 days, $e = 0·00$, and $K = 11·37$ km., with a probable error of a normal place of weight unity of ±0·52 km. per second.

H. R. 6506

The star H. R. 6506 (H. D. 158261) α (1900) = $17^h\ 23^m·2$, δ (1900) = $+34°\ 47'$, was suspected to be a binary by Dr. Young from eyepiece estimates of the first few plates obtained in 1923. Subsequent measures of these plates by the writer on the micrometer confirmed the binary character of the star. Dr. Young then very kindly handed over the star to the writer for further investigation, and additional plates were obtained in 1923, 1924 and 1925. Thirty-five of the thirty-seven plates obtained have been used in determining the orbital elements, the two discarded being unsuitable for accurate measurement.

All the plates have been taken with the single-prism camera attached to the 72-inch telescope, which gives a dispersion of 29 angstroms per millimeter at Hγ. The emulsion of the majority of the plates is Seed 30, a few of the last, however, being taken on the new Eastman 40. These plates were all measured in the usual manner on the micrometer microscope.

The spectrum of this star consists of many sharp lines suitable for accurate measurement, and the type, from the inspection of our plates, is A2, somewhat later than that of B9 as given in the H.R. and H.D. catalogues. The spectrum of the secondary component has been suspected at times, but it is very faint, if present at all, being blotted out by the continuous spectrum of the brighter component.

24500

The following table gives the data of the observations. The phases are based on the final elements and the residuals are the "O–C" of the final ephemeris. It should be noted here that the observations are given in G.M.T. as used prior to 1925. The observers represented by the initials in the last column are:—C, Christie; H, Harper; P′, H. H. Plaskett; Pe, Pearce; S, Smith, and Y, Young.

OBSERVATIONS OF H.R. 6506

No.	Date	Julian Date	Phase	Velocity	Residuals	Lines	Observer
1	1923 June 17	2,423,588·822	3·295	−34·6	+1·6	20	Y
2	" 26	3,597·712	0·349	− 8·6	−0·3	14	C
3	" 28	3,599·819	2·456	−41·6	+0·9	17	Y
4	" 30	3,601·816	4·453	− 6·2	+2·2	17	Y
5	July 3	3,604·776	1·495	−42·4	−4·1	18	C
6	" 12	3,613·741	4·541	− 6·1	+0·4	15	Y
7	" 19	3,620·718	5·600	+ 2·1	0·0	14	C
8	" 21	3,622,805	1·769	−42·7	+0·3	14	C
9	" 22	3,623·737	2·701	−46·8	−1·3	18	Y
10	" 28	3,629·748	2·794	−46·8	−2·2	5	Y
11	Aug. 2	3,634·735	1·862	−43·9	+0·4	19	Y
12	" 3	3,635·744	2,871	−43·6	−0·1	15	H
13	" 5	3,637·719	4·846	− 3·0	−2·0	16	Y
14	" 9	3,641·689	2·898	−40·9	+2·4	12	Y
15	" 14	3,646·780	2·071	−45·8	+0·5	17	C
16	" 29	3,661·703	5·158	+ 1·0	−1·3	15	C
17	" 29	3,661·835	5·290	+ 4·8	+1·9	12	C
18	Sept. 16	3,679·669	5·378	+ 1·7	−1·3	12	C
19	" 22	3,685·658	5·440	+ 3·8	+0·9	11	C
20	" 26	3,689·637	3·501	−33·1	−1·1	15	Y
21	" 29	3,692·618	0·563	−12·8	+1·5	13	Y
22	1924 May 21	3,927·931	5·067	+ 3·5	+1·8	12	C
23	July 3	3,970·856	0·646	−15·0	+1·9	12	C
24	July 4	3,971·803	1·593	−41·9	−1·8	12	H
25	" 8	3,975·805	5·595	+ 1·0	−1·1	15	S
26	" 9	3,976·779	0·651	−15·2	+1·5	14	C
27	" 10	3,977·783	1·655	−40·8	+0·3	12	Y
28	" 11	3,978·808	2·680	−46·2	−0·5	10	S
29	" 12	3,979·816	3·788	−32·7	−7·7	12	C
30	Sept. 11	4,040·685	5·375	+ 2·0	−1·1	16	Y
31	1925 May 24	4,295·863	0·152	− 6·5	−2·0	11	C
32	" 25	4,296·825	1·114	−28·4	+0·9	11	H
33	" 28	4,299·769	4·058	−21·4	−3·4	10	Pe
34	June 9	4,311·736	4·189	−10·0	+4·6	12	P′
35	" 20	2,424,322·802	3·418	−31·1	+2·7	13	C

The preliminary elements were obtained by King's graphical method. No difficulty was encountered with the period, and, as 120 cycles took place between the first and last observations, the period so found was accepted as final and not included in the least-squares solution.

The preliminary elements, then, were:

PRELIMINARY ELEMENTS

Period	P	=	5·9182 days
Eccentricity	e	=	0·05
Longitude of periastron	ω	=	30°
Velocity of system	γ	=	+22·56 km.
Semi-amplitude of range	K	=	24·5 km.
Date of periastron passage	T	=	J.D. 2,423,585.430

Making the usual transformations

$$\text{Let } x = \delta\gamma$$
$$y = \delta K$$
$$z = K.\delta e$$
$$u = -K.\delta\omega$$
$$v = \frac{K.\mu}{(1-e^2)^{\frac{1}{2}}}\,\delta T$$

the following 35 observations equations were built up, all plates being of equal weight.

OBSERVATION EQUATIONS OF H.R. 6506

1	1·000x	−0·548y	+0·228z	−0·782u	−0·734v	−1·4 = 0
2	1·000	+0·550	−0·003	+0·887	+0·937	−0·5
3	1·000	−0·950	+0·958	−0·094	−0·108	+0·3
4	1·000	+0·549	−0·863	−0·837	−0·862	−2·9
5	1·000	−0·631	+0·722	+0·764	+0·722	+4·4
6	1·000	+0·639	−0·742	−0·778	−0·815	−0·9
7	1·000	+1·010	+1·004	+0·278	+0·278	+0·1
8	1·000	−0·807	−0·052	+0·551	+0·501	+0·4
9	1·000	−0·892	+0·978	−0·328	−0·320	+2·4
10	1·000	−0·859	+0·930	−0·408	−0·391	+3·2
11	1·000	−0·852	+0·130	+0·471	+0·422	+0·5
12	1·000	−0·823	+1·869	−0·475	−0·500	+0·9
13	1·000	+0·866	−0·173	−0·543	−0·592	+1·7
14	1·000	−0·808	+0·836	−0·500	−0·474	−1·5
15	1·000	−0·928	+0·538	+0·265	+0·224	+0·5
16	1·000	+1·016	+0·545	−0·204	−0·246	+1·3
17	1·000	+1·037	+0·792	−0·037	−0·067	−1·9
18	1·000	+1·043	+0·856	+0·014	−0·011	+1·3
19	1·000	+1·041	+0·928	+0·094	+0·075	−0·9
20	1·000	−0·406	−0·106	−0·868	−0·828	+0·6
21	1·000	+0·329	−0·477	+0·983	+1·028	−1·7
22	1·000	+0·984	+0·339	−0·313	−0·360	−2·0
23	1·000	+0·227	−0·650	+1·007	+1·047	−2·0
24	1·000	+0·704	−0·390	+0·690	+0·644	+2·1
25	1·000	+1·010	+1·003	+0·278	+0·278	+1·2
26	1·000	+0·230	−0·654	+1·007	+1·057	−1·7
27	1·000	−0·743	−0·274	+0·643	+0·596	±0·0
28	1·000	−0·899	+0·985	−0·310	−0·303	+1·6
29	1·000	−0·106	−0·660	−0·964	−0·928	+7·6
30	1·000	+1·043	+0·865	+0·024	±0·000	+1·0
31	1·000	+0·727	+0·433	+0·754	+0·080	+1·8
32	1·000	−0·285	−1·003	+0·969	+0·962	−1·1
33	1·000	+0·177	+0·955	−0·966	−0·954	+3·2
34	1·000	+0·298	+0·993	−0·942	−0·938	−5·3
35	1·000	+0·449	+0·001	−0·845	−0·797	−2·5

From these observation equations the following normal equations were formed.

$$\begin{array}{rrrrrrr} 35{\cdot}000x & +\ 3.392y & +11{\cdot}402z & -\ 0{\cdot}514u & -\ 0{\cdot}697v & +\ 9{\cdot}800 & = 0 \\ & +20{\cdot}012 & -\ 0{\cdot}192 & +\ 0{\cdot}554 & +\ 0{\cdot}679 & -11{\cdot}663 & \\ & & +21{\cdot}701 & -\ 3{\cdot}978 & -\ 3{\cdot}440 & +11{\cdot}127 & \\ & & & +14{\cdot}943 & +14{\cdot}435 & -\ 2{\cdot}229 & \\ & & & & +14{\cdot}868 & -\ 4{\cdot}433 & \end{array}$$

the solution of which gave the following corrections:

$$\begin{array}{lllll} x = -0{\cdot}17 & \text{or} & \delta\gamma = -0{\cdot}17 \text{ km/sec.} \\ y = +0{\cdot}59 & & \delta K = +0{\cdot}59 \text{ km/sec.} \\ z = -0{\cdot}465 & & \delta e = -0{\cdot}019 \\ u = -2{\cdot}456 & & \delta\mu = +5^\circ{\cdot}74 \\ v = +2{\cdot}540 & & \delta T = +0{\cdot}0956 \text{ days} \end{array}$$

The final elements with their probable errors are, then,

Final Elements

$$\begin{array}{rlll} P & = & 5{\cdot}9182 \text{ days} & \\ e & = & 0{\cdot}031 & \pm\ 0{\cdot}016 \\ \omega & = & 35^\circ{\cdot}74 & \pm\ 5^\circ{\cdot}33 \\ \gamma & = & -22{\cdot}73 \text{ km/sec.} & \pm\ 0{\cdot}14 \text{ km/sec.} \\ K & = & 25{\cdot}09 \text{ km.} & \pm\ 0{\cdot}38 \text{ km.} \\ T & = & 2{,}423{,}585{\cdot}527 & \pm\ 0{\cdot}064 \text{ days} \\ a \sin i & = & 2{,}041{,}000 \text{ km.} & \\ \dfrac{m_1^3 \sin^3 i}{(m+m_1)^2} & = & {\cdot}00970\ \odot & \end{array}$$

The sum of the squares of the residuals was reduced from 191·6 to 171·3, or a little more than 10 per cent. Evidently then, the preliminary elements were close approximations to the true value judging from this small reduction.

The probable error of a single plate is ±1·5 km/sec. The individual measures are plotted on the accompanying graph, Fig. 1, of the final elements.

Dominion Astrophysical Observatory,
Victoria, B.C., August, 1925.

H. R. 5752

The star H. R. 5752 (H.D. 138213), co-ordinates for 1900 $\alpha = 15^h\ 25^m{\cdot}6$, $\delta = +47^\circ\ 35'$, was found to be a spectroscopic binary by the writer from measures of four spectrograms taken by Mr. H. H. Plaskett in 1922, and was announced as such in the Journal of the R.A.S.C. for April 1924. Thirty-seven additional spectrograms were secured during the summer of 1925 in order to determine the orbit of this star. These spectrograms were all made on Eastman 40 plates with single-prism and the medium-focus camera of the universal spectrograph attached to the 72-inch telescope, which

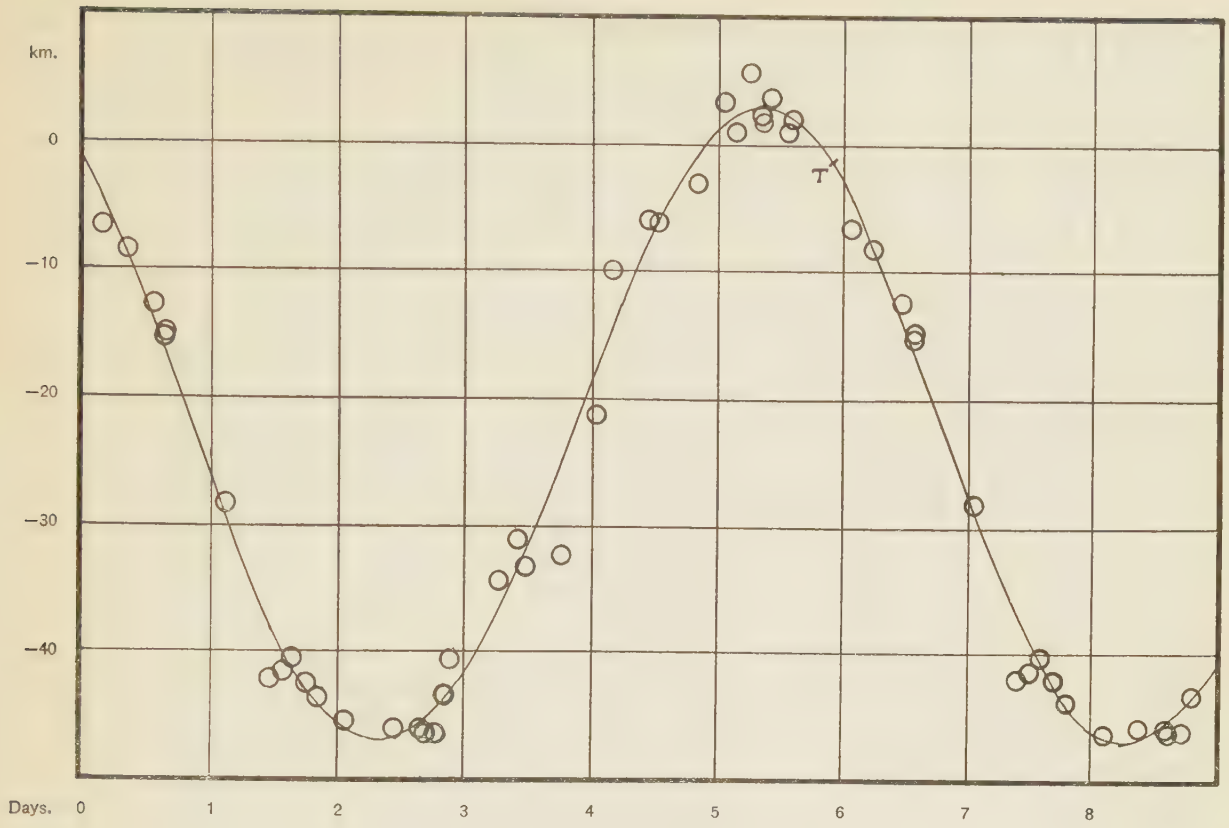

Fig. 1. Radial Velocity Curve of H.R. 6506.

combination gives a dispersion of about 29A per mm. at Hγ. All plates were measured on the spectrocomparator using Procyon as a standard, and were reduced by Hartmann's short method.

Some difficulty was encountered in determining the period of this star, due to the fact that the period is very close to one day and that, during the latter part of the summer, the observations had to be made at approximately the same hour angle. The first period found which appeared satisfactory was of 1·0060 days, but owing to the large eccentricity, 0·3, obtained by the use of this period, it was looked upon with suspicion, for such an eccentricity is very unusual for so short a period. Further plates were then obtained in order to test this period and measures of these plates fell off the curve so much as to render the formerly suspected period no longer tenable. After further trials a period of 1·0085 days was found, which satisfied all the observed velocities within the errors of observation and this was considered as correct.

The forty-one velocities were then grouped into ten normal places according to phase and, as they appeared to fit most closely a sine curve, the eccentricity was considered as zero and a least-squares solution was made for the most probable values of T, K and γ. As some thirteen hundred revolutions of this system had taken place between the first and last observations the period was not included in the solution. The time of periastron passage, T, was taken as that point where the velocity curve crosses the γ axis with the velocities becoming positive.

The following table gives the observational data, the phases being based on the final elements.

OBSERVATIONS OF H.R. 5752

No.	Date	Julian Date	Phase	Velocity	O–C	Regions	Observer
1	1922 Feb. 26	2,423,113·071	·910	−26·0	+0·6	1 = 23	P′
2	Mar. 24	138·986	·605	−20·3	+3·4	1 = 23	P′
3	April 18	163·948	·354	−12·0	−4·1	11 = 23	P′
4	May 9	184·849	·073	−11·5	+0·6	1 = 23	P′
5	1925 May 25	4,295·797	·662	−23·5	+3·0	7 = 23	C
6	June 19	320·765	·418	− 9·3	+1·9	1 = 23	H
7	June 21	322·758	·404	−10·8	−0·4	1 = 23	C
8	" 23	324·869	·488	−16·2	−0·3	7 = 23	H
9	July 6	337·844	·354	− 1·3	+6·6	1 = 23	C
10	" 7	338·803	·303	− 4·9	+1·3	5 = 23	H
11	" 9	340·746	·229	− 7·3	−1·5	1 = 23	C
12	" 11	342·726	·192	− 8·3	−2·9	1 = 23	H
13	" 17	348·758	·173	− 6·0	+1·0	7 = 23	C
14	" 19	350·805	·203	− 6·4	−0·2	1 = 23	H
15	" 20	351·707	·086	− 9·9	+1·4	1 = 23	C
16	" 28	359·735	·056	−13·0	+0·2	1 = 23	H
17	" 30	361·721	·025	−16·7	−0·2	1 = 23	C
18	" 31	362·721	·017	−19·1	−2·3	7 = 23	H
19	Aug. 1	363·696	·991	−15·0	+2·0	3 = 23	P′
20	" 3	365·708	·986	−18·6	0·0	9 = 23	C
21	" 4	366·722	·992	−14·6	+3·6	1 = 23	H
22	" 6	368·733	·986	−22·4	−3·8	7 = 23	C
23	" 7	369·706	·950	−18·3	+3·7	7 = 23	Pe
24	" 8	370·774	·002	−20·3	−3·4	15 = 23	H
25	" 13	375·692	·876	−23·0	+3·4	5 = 23	C
26	" 17	379·666	·826	−30·4	−3·4	9 = 23	C
27	" 17	379·676	·835	−27·1	0·0	9 = 23	C
28	" 17	379·737	·896	−21·2	+3·1	9 = 23	C
29	" 17	379·753	·912	−24·7	+3·1	1 = 23	C
30	" 18	380·711	·862	−28·4	−2·3	7 = 23	H
31	" 20	382·677	·811	−27·1	+0·6	1 = 23	C
32	" 23	385·673	·782	−29·9	−1·6	1 = 23	C
33	" 27	389·678	·753	−26·0	+2·2	1 = 23	H
34	" 31	393·625	·686	−28·2	−0·9	3 = 23	C
35	" 31	393·657	·698	−26·9	+0·7	1 = 23	C
36	Sept. 10	402·651	·615	−23·8	+0·5	7 = 23	C
37	" 12	404·637	·584	−26·3	−3·9	1 = 23	H
38	" 17	410·626	·522	−20·2	−2·0	1 = 23	C
39	" 17	410·699	·595	−25·9	−3·0	1 = 23	C
40	" 22	415·626	·460	−19·7	−5·4	1 = 23	C
41	" 28	2,424,421·615	·418	− 7·4	+5·9	9 = 23	C

From these observations the following normal places were formed:

NORMAL PLACES

No.	Mean Phase	Mean Velocity	Weight	No.	Mean Phase	Mean Velocity	Weight
1	·051	−12·8	4	6	·603	−24·0	5
2	·190	− 7·0	4	7	·703	−27·0	3
3	·328	− 6·1	3	8	·805	−28·6	4
4	·404	− 9·2	3	9	·877	−24·7	5
5	·481	−18·7	3	10	·975	−18·3	7

The preliminary elements, found by King's graphical method, were:—

PRELIMINARY ELEMENTS

Period	P	=	1·0085 days
Eccentricity	e	=	0·00
Velocity of system	γ	=	−17·2 km./sec.
Semi-amplitude of range	K	=	12·2 km.
Date of periastron passage	T	=	2,423,112·170

Making the usual transformations

let $x = \delta\gamma$
$y = \delta K$
$z = -K.\mu.\delta T$

the following equations were formed from the normal places:—

OBSERVATION EQUATIONS

1·000x	+0·334y	+0·942z	−0·3 = 0
1·000	+0·927	+0·376	+1·2
1·000	+0·890	−0·455	−0·2
1·000	+0·582	−0·813	−0·9
1·000	+0·145	−0·989	+3·3
1·000	−0·582	−0·813	−0·3
1·000	−0·947	−0·321	−1·8
1·000	−0·957	+0·305	−0·3
1·000	−0·725	+0·689	−1·4
1·000	−0·198	+0·980	−1·3

From these observation equations the following normal equations were derived:

4·100x	−0·466y	+0·500z	−1·400	= 0
	+1·829	−0·217	+1·739	
		+2·262	−1·775	

the solution of which gave the following:

x	=	+0·164	or	$\delta\gamma$	= −·164 km./sec.
y	=	−0·830		δK	= −0·830
z	=	+0·670		δT	= −0·0088 days

Making these corrections to the preliminary elements, we have for the final elements and their probable errors:

FINAL ELEMENTS

P	=	1·0085 days	
e	=	0·00	
γ	=	−17·04 km./sec.	± 0·26 km./sec.
K	=	11·37 km.	± 0·39 km.
T	=	J.D. 2,423,112·161	± 0·00496 days
$a \sin i$	=	157,700 km.	
$\frac{m_1 \sin^3 i}{(m_1+m_2)^2}$	=	0·00015 ⊙	

The sum of the squares of the residuals was reduced from 7·67 to 4·29, or about 44 per cent.

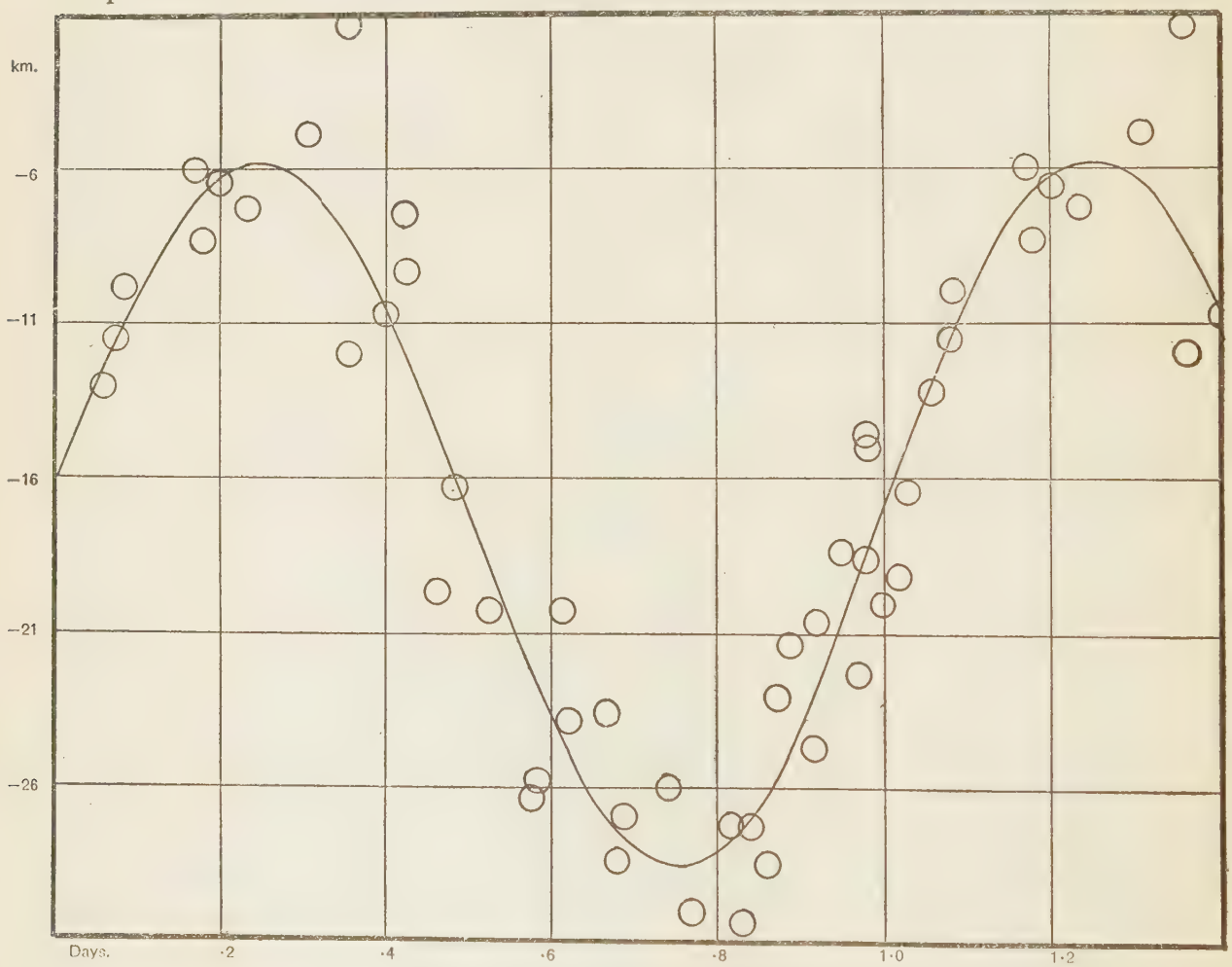

Fig. 2. Radial Velocity Curve of H.R. 5752.

The probable error of a single plate is ±1·91 km./sec. and of a normal place of weight unity ±0·52 km./sec. The accompanying velocity curve, Fig. 2, is plotted from the final elements, the individual observations being indicated by open circles.

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THE ORBITS OF THREE A-TYPE SPECTROSCOPIC BINARIES

BY W. E. HARPER

GENERAL ABSTRACT

The three stars under consideration are H.R. 4750, H.R. 8169 and Boss 5579. All three were discovered at this observatory. The second and third show the spectrum of the secondary component. In Boss 5579 the components are of nearly equal intensity but in the case of H.R. 8169 the main one has an intensity about six times that of the secondary. The minimum value for the combined mass of Boss 5579 is 1·9 and for H.R. 8169 it is 3·0 times that of the sun. Considerable time was expended before the period of Boss 5579 was secured whereas that of H.R. 4570 revealed itself from the start. The last mentioned star has beautiful sharp lines and yields a probable error of a plate of only ±1·2 km. per sec., while for H.R. 8169 it is ±3·1 and for Boss 5579 it is ±10·3 km. per sec.

H.R. 4750

ABSTRACT

Sixteen spectrograms of this A3-type star taken during the present season are made the basis of a determination of the spectroscopic orbit. The spectrum contains numerous sharp lines suitable for measurement so that the probable error of a plate is only ±1·2 km. per sec. The period is 11·782 days and eccentricity ·060.

The star H.R. 4750 (1900 $\alpha = 12^h\,23^m\cdot7$, $\delta = +26°\,47'$) whose visual magnitude is 6·48 and type A3, was discovered to be a binary by the writer from the first two plates made here early this year. The spectrum contains numerous metallic and other lines and thus is one permitting of fairly accurate measurement. The period, determined approximately as 11·76 days from a graph of the observations, was incorporated with the other elements in a least-squares solution.

The following table gives the data of the observations. The time is given as Greenwich Mean Time in the sense used prior to the year 1925. The phases are reckoned from the final values of the period and periastron passage. The residuals are computed directly as each observation was treated separately in the least-squares solution.

OBSERVATIONS OF H.R. 4750

Plate Number	Date	Julian Date	Phase	Velocity	O-C
12885	1926 Feb. 27	2,424,574·926	1·426	−16·2	+0·5
13238	April 12	618·913	10·067	−30·2	+2·3
13336	" 27	633·795	1·384	−16·2	+1·4
13353	May 3	639·830	7·419	+18·5	−1·2
13360	" 5	641·788	9·377	−18·1	+2·1
13376	" 10	646·733	2·540	+ 5·2	−3·4
13392	" 12	648·797	4·604	+41·4	+2·5
13398	" 14	650·772	6·579	+32·2	−0·1
13404	" 20	656·717	0·742	−29·4	+0·9
13433	" 30	666·756	10·781	−42·9	−2·6
13455	June 2	669·804	2·047	− 1·7	+0·8
13466	" 5	672·834	5·077	+40·4	−0·2
13492	" 10	677·792	10·035	−34·3	−2·4
13547	" 17	684·749	5·209	+40·4	−0·3
13555	" 19	686·819	7·279	+22·9	+0·7
13604	" 27	2,424,694·749	3·427	+24·8	−1·0

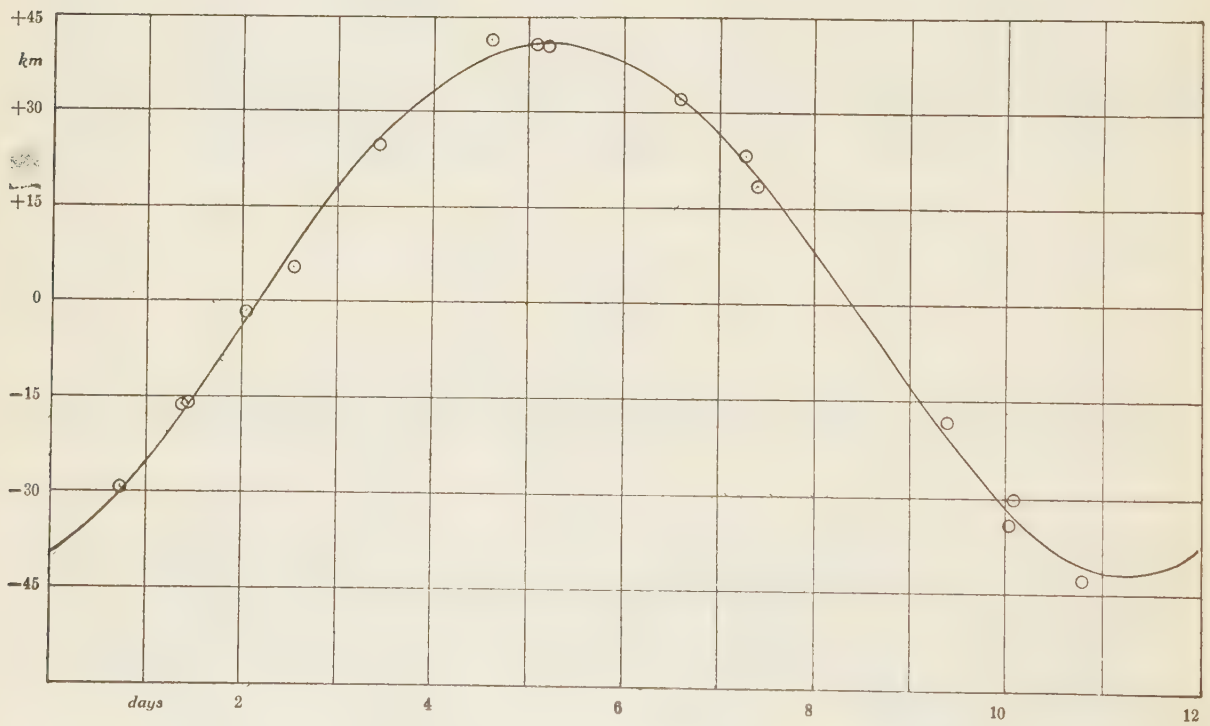


Fig. 1 Velocity Curve of H.R. 4750 Showing Individual Observations

PRELIMINARY ELEMENTS

$$
\begin{aligned}
P &= 11{\cdot}76 \text{ days} \\
e &= \cdot 05 \\
\omega &= 180^\circ \\
\gamma &= +2{\cdot}0 \text{ km.} \\
K &= 42{\cdot}0 \text{ km.} \\
T &= \text{J.D. } 2{,}424{,}584{\cdot}790
\end{aligned}
$$

Making the following substitutions,

$$
\begin{aligned}
x &= \delta\gamma \\
y &= \delta K \\
z &= K\,\delta e \\
u &= -K.\,\delta\omega \\
v &= -\frac{100\,K}{(1-e^2)^{\frac{3}{2}}}\,\delta\mu \\
w &= \frac{K\mu}{(1-e^2)^{\frac{3}{2}}}\,\delta T
\end{aligned}
$$

the observation equations connecting the residuals with the preliminary values of the elements are as follows.

OBSERVATION EQUATIONS

1	1·000x	−0·747y	+0·048z	−0·717u	−0·552v	−0·766w	−0·0	= 0
2	1·000	−0·504	+0·611	−0·891	−0·093	−0·932	−3·0	
3	1·000	−0·468	+0·671	−0·908	−0·463	−0·946	−1·5	
4	1·000	−0·081	+1·008	−1·000	−0·853	−1·004	+0·3	
5	1·000	+0·154	+0·912	−0·979	−0·594	−0·959	+3·3	
6	1·000	+0·601	+0·134	−0·759	−0·780	−0·709	+2·4	
7	1·000	+0·897	−0·799	−0·321	−0·187	−0·291	−1·7	
8	1·000	+0·947	−0·989	−0·077	−0·061	−0·069	+1·4	
9	1·000	+0·950	−1·000	+0·000	+0·000	+0·000	+1·5	
10	1·000	+0·755	−0·308	+0·593	+0·361	+0·547	+1·5	
11	1·000	+0·476	+0·432	+0·851	+0·833	+0·807	−0·9	
12	1·000	+0·452	+0·480	+0·865	+0·453	+0·823	+2·5	
13	1·000	−0·548	+0·526	+0·867	+0·519	+0·910	−2·9	
14	1·000	−0·827	−0·191	+0·629	+0·230	+0·677	−2·5	
15	1·000	−0·856	−0·284	+0·592	+0·595	+0·640	+0·4	
16	1·000	−1·028	−0·914	+0·206	+0·186	+0·227	+1·7	

From these were obtained the normal equations as follows:—

16·000	+0·173y	+0·337z	−1·049u	−0·406v	−1·045w	+2·500	= 0
	7·802	−1·881	+0·053	−0·341	−0·006	+8·768	
		7·048	−2·278	−1·336	−2·385	−3·099	
			8·139	+5·291	+8·183	−2·093	
				3·996	+5·272	−3·482	
					8·246	−2·092	

30024—1½

which resulted in the corrections,

$$\begin{aligned} \delta\gamma &= -\cdot 21 \text{ km.} \\ \delta K &= -\cdot 73 \text{ km.} \\ \delta e &= +\cdot 010 \\ \delta\omega &= +18^\circ\cdot 50 \\ \delta P &= +\cdot 022 \text{ days} \\ \delta T &= +\cdot 492 \text{ days} \end{aligned}$$

The sum of the squares of the residuals was reduced from 57·0 to 47·7, the probable error of a plate being ±1·20 km. per sec.

FINAL VALUES

P	=	11·782 days	±·024 days
e	=	·060	±·015
ω	=	198°·50	±20°·40
γ	=	+1·79 km.	±·37 km.
K	=	41·27 km.	±·60 km.
T	=	J.D. 2,424,585,282	±·622 days
$a \sin i$	=	6,674,300 km.	

In the accompanying graph individual observations are plotted.

H.R. 8169

ABSTRACT

The orbit of this double-lined spectroscopic binary of type A0 is based upon 25 spectrograms taken during the years 1925 and 1926. The period is 20·30 days and eccentricity 0·441. The intensities of the lines of the main component are at least six times as great as those of the fainter. The masses are respectively 1·87 and 1·08 times that of the sun.

The star H.R. 8169 (1900 $\alpha = 21^h\ 17{\cdot}1^m$, $\delta = +32°\ 11'$) whose visual magnitude is 6·03 and type AO, was discovered to be a spectroscopic binary by the author in July, 1925. Eight plates were secured that year and seventeen this year. On ten of the plates the spectrum of the second component was measured so that the orbit is based upon 25 measures of the primary and 10 of the secondary. They were all made with the single-prism equipment, giving a linear dispersion at Hγ of 29 Angstroms per millimetre.

The spectrum consists of strong hydrogen lines with fairly strong calcium λ3933 and fainter magnesium λ4481. All these are well defined lines and upon them the results chiefly depend. In addition there is a background of numerous fainter metallic lines among which λ4045 and λ4233 are the strongest. All these fainter lines are likewise well defined and give accordant results when measured which was mostly possible when the spectra were fairly well superposed. For component I, the least number of lines measured was five, the greatest thirteen, and the average a little over eight. Many of the plates were measured twice. The spectrum of the secondary is much less intense than that of the primary, the difference being as marked as any that has come to the writer's attention. Probably a ratio of 6 to 1 would not be overstating the case as may be seen from the accompanying reproduction where the best plate is enlarged. On this plate six lines of the secondary spectrum were measured, but on the nine others showing the fainter spectrum only the lines λ4481 and λ3933 were measurable and quite often λ4481 was of very uncertain value.

OBSERVATIONS OF H.R. 8169

Plate No.	Date	Julian Date G.M.T.	Phase	Component I			Component II		
				Velocity	Wt.	O-C	Velocity	Wt.	O-C
11910	1925 July 18	2,424,350·932	7·674	+17·8	0·9	−5·8			
11985	" 27	359·944	16·686	−38·3	0·7	−7·6	+ 51·4	0·1	+ 9·3
12191	Aug. 29	393·898	10·040	+18·0	0·9	+2·0			
12338	Sept. 21	415·802	11·644	+16·8	0·9	+8·4			
12541	Oct. 19	443·687	19·229	−68·9	0·8	−4·5	+102·2	0·3	+ 1·8
12567	" 24	448·722	3·964	+20·0	0·4	−3·6	− 64·2	0·1	−12·5
12569	" 30	454·673	9·915	+12·6	0·9	−3·6			
12712	Dec. 28	513·575	7·917	+25·4	0·9	+2·3			
13629	1926 June 28	695·961	7·603	+30·2	0·6	+6·5	− 61·2	0·2	− 9·2
13652	July 1	698·890	10·532	+ 6·6	0·6	−7·4			
13749	" 9	706·915	18·557	−53·6	0·6	+4·0	+ 90·0	0·3	+ 1·0
13771	" 11	708·970	0·312	−48·6	0·6	−3·6			
13800	" 17	714·929	6·271	+31·2	0·4	+5·1			
13818	" 19	716·863	8·205	+19·7	0·7	−2·7			

OBSERVATIONS OF H.R. 8169—*Concluded*

Plate No.	Date	Julian Date G.M.T.	Place	Component I			Component II		
				Velocity	Wt.	O-C	Velocity	Wt.	O-C
13847	July 21	718·932	10·274	+11·4	0·5	−3·6			
13862	" 26	723·915	15·257	−10·2	0·7	+5·1			
13899	" 31	729·009	0·051	−52·9	0·5	+0·2	+ 79·1	0·1	− 2·0
13917	Aug. 2	730·893	1·935	+ 4·0	0·8	0·0			
13952	" 5	733·889	4·931	+22·6	0·5	−3·9			
14001	" 18	746·877	17·919	−50·7	0·6	−2·8	+ 49·4	0·1	−22·5
14012	" 20	748·888	19·930	−59·4	0·8	+2·6	+ 93·5	0·5	− 2·5
14048	" 22	750·912	1·654	− 3·8	0·8	−0·6			
14093	" 30	758·744	9·486	+20·1	0·7	+2·1			
14157	Sept. 8	767·825	18·567	−15·1	0·6	+5·5	+ 90·0	0·2	+ 1·2
14208	" 13	2,424,772·794	3·236	+24·2	0·6	+4·6	− 67·6	0·1	−22·9

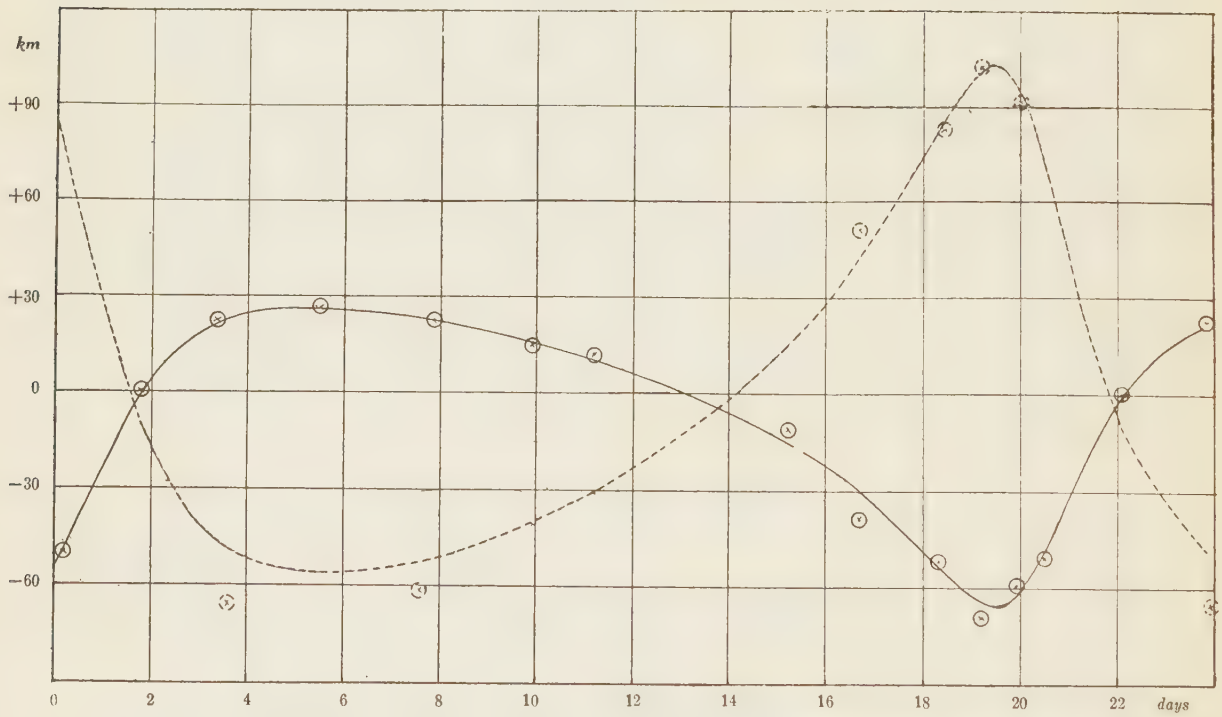


FIGURE 2—Velocity Curves of H.R. 8160 Showing Grouped Observations

The period determined from the two years' observations was 20·30 days and this value was considered definitive. The observations were grouped according to phase into 18 normal places, twelve representing component I, and six component II. In seeking for preliminary values of the elements to satisfy the observations there appeared to be a difference in the value of the velocity of the system for the two components. Component II seemed to require a systematic velocity 8 or 10 km. more negative than component I, whereas, of course, they must be identical. No explanation seems possible for this and

some other similar cases on record. Whatever distortion, due to "turbidity" or other causes, there is in the case of close spectral lines one would think it should be equally operative whether the fainter was to the redward or violet side of the stronger line and thus to a large extent eliminate itself from the systematic velocity. The question may be looked into further when more data are at hand but for the present, as the relative weights of the observations for the two components are as 17 to 2, it was decided to determine a set of elements to suit the primary and then secure the best value of the semi-amplitude of the secondary, consistent with the elements so determined.

NORMAL PLACES (MAIN COMPONENT)

—	Mean Phase		Mean Vel.	Wt.	O-C	
	Prel.	Final			Prel.	Final
1	7·966	7·851	+22·8	3·1	+1·2	−0·2
2	10·027	9·912	+15·8	3·0	+0·3	−0·8
3	11·314	11·199	+12·7	1·5	+2·4	+1·5
4	15·372	15·257	−10·2	0·7	+5·2	+5·1
5	16·801	16·686	−38·3	0·7	−7·5	−7·6
6	18·643	18·348	−51·8	1·8	+4·4	+2·5
7 ÷	19·344	19·229	−68·9	0·8	−0·8	−4·5
8	20·045	19·930	−59·4	0·8	+5·6	+2·7
9	0·308	0·193	−50·6	1·1	−1·7	−1·3
10	1·909	1·794	+ 0·1	1·6	−2·4	+0·1
11	3·642	3·527	+22·5	1·0	+1·1	+1·0
12	5·642	5·527	+26·4	0·9	+1·4	+0·2

Preliminary Elements

$$
\begin{aligned}
P &= 20\cdot30 \text{ days} \\
e &= \cdot47 \\
\omega_1 &= 218^\circ \\
\gamma &= -4\cdot59 \text{ km./sec.} \\
K &= 47\cdot0 \text{ km./sec.} \\
T &= \text{J.D. } 2{,}424{,}363\cdot443
\end{aligned}
$$

From these elements observation equations of the usual form were built up connecting the residuals with the elements. In these, for the sake of homogeneity, the following substitutions were made.

$$
\begin{aligned}
x &= \delta\gamma \\
y &= \delta K_1 \\
z &= K_1 \delta e \\
u &= -K_1\, \delta\omega \\
v &= 21\cdot155\, \delta T
\end{aligned}
$$

OBSERVATION EQUATIONS FOR COMPONENT I

1	1·000x	+0·558y	−0·995z	+0·082u	+0·112v	−1·2	= 0
2	1·000	+0·428	−0·808	+0·314	+0·169	−0·3	
3	1·000	+0·318	−0·577	+0·436	+0·207	−2·4	
4	1·000	−0·229	+0·675	+0·701	+0·433	−5·2	
5	1·000	−0·557	+1·212	+0·693	+0·605	+7·5	
6	1·000	−1·098	+1·014	+0·397	+0·787	−4·4	
7	1·000	−1·351	−0·347	−0·093	+0·334	+0·8	
8	1·000	−1·284	−1·097	−0·696	−0·863	−5·6	
9	1·000	−0·942	−0·031	−1·109	−1·722	+1·7	
10	1·000	+0·151	+1·447	−1·143	−0·949	+2·4	
11	1·000	+0·553	−0·029	−0·673	−0·227	−1·1	
12	1·000	+0·630	−0·823	−0·259	+0·012	−1·4	

From these there resulted the normal equations:—

17·000x	−0·817	− 2·875z	−1·405u	−0·742v	−15·020	= 0
	8·545	− 4·218	+0·756	+0·610	+ 5·299	
		13·749	−1·508	−0·260	+13·645	
			5·918	+5·834	− 6·557	
				7·129	− 8·495	

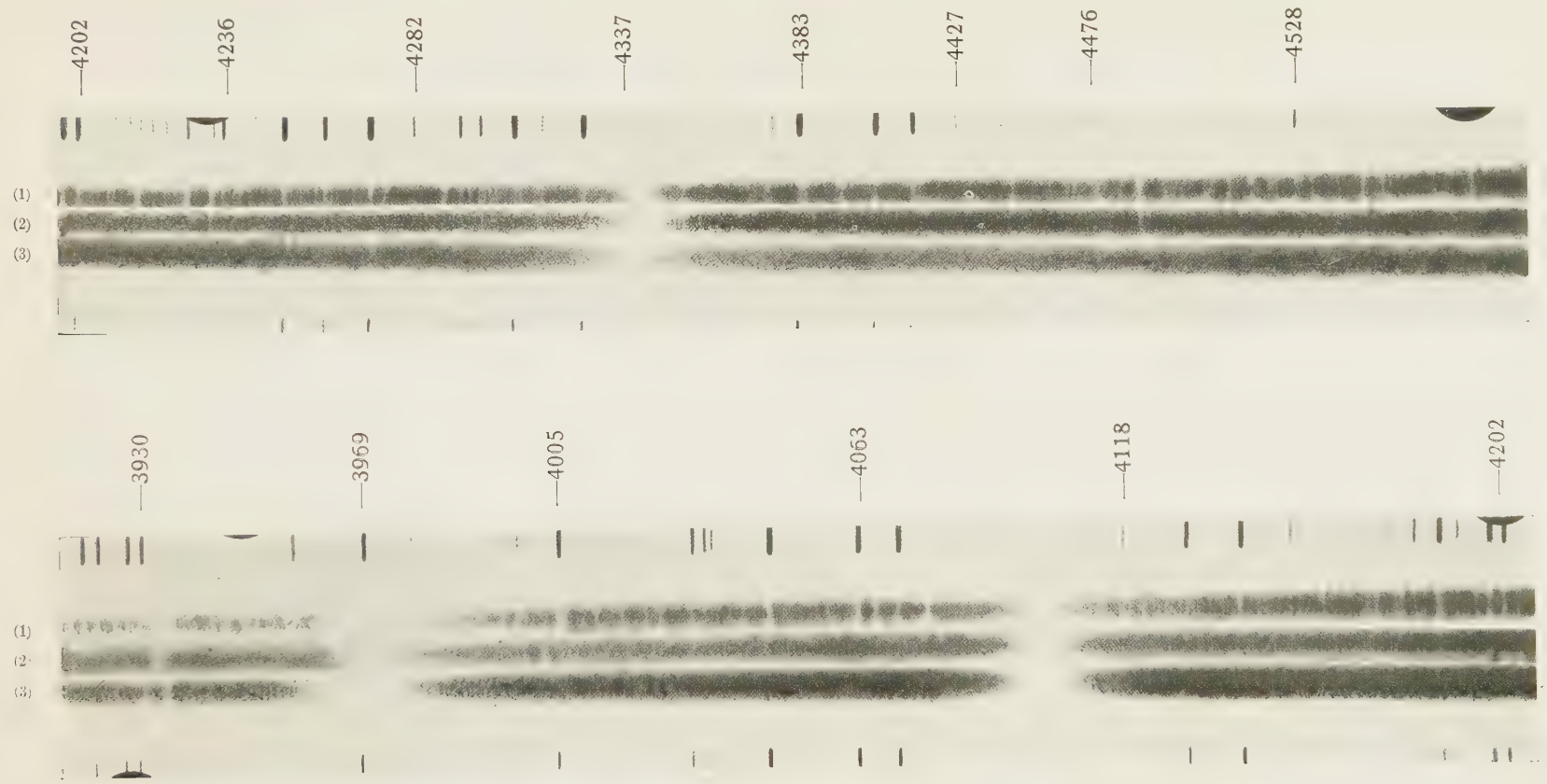
which gave corrections to the preliminary elements as follows:—

$$\begin{aligned} \delta\gamma &= + \cdot 61 \text{ km./sec.} \\ \delta K_1 &= -1 \cdot 29 \text{ km./sec.} \\ \delta e &= - \cdot 029 \\ \delta\omega &= +1^\circ \cdot 67 \\ \delta T &= +0 \cdot 115 \text{ days} \end{aligned}$$

The solution improved the agreement and resulted in a lowering of Σpvv for the normal places from 147·5 to 100·0. With the revised elements and a value for K_2 of 84, a set of observation equations for the six normal places of component II was built up.

NORMAL PLACES (COMPONENT II)

—	Mean Phase Final	Mean Velocity	Wt.	O-C	
				Prel.	Final
13	7·603	− 61·2	0·2	− 6·1	− 9·0
14	16·686	+ 51·4	0·1	+ 6·3	+ 9·3
15	18·454	+ 83·2	0·6	− 8·2	− 2·4
16	19·229	+102·2	0·3	− 4·9	+ 1·8
17	20·000	+ 91·1	0·6	− 9·8	− 3·4
18	3·600	− 65·9	0·2	−14·3	−17·2



Spectra of (1) H.R. 4750 (2) H.R. 8169 (3) Boss 5579

Enlarged 19.1 diameters

OBSERVATION EQUATIONS FOR COMPONENT II

13	$-0{\cdot}609K_2$	+ 6·1	= 0
14	+0·584	− 6·3	
15	+1·135	+ 8·2	
16	+1·322	+ 4·9	
17	+1·248	+ 9·8	
18	−0·567	+14·3	

These when solved gave a correction to K_2 of $-5{\cdot}05$ and reduced Σpvv for the normal places from 157·4 to 95·5. Satisfactory agreement was obtained between equation and ephemeris residuals in both cases so that one solution was sufficient. The combined total *pvv* for both components was thus reduced from 304·9 to 195·5, about 36 per cent.

The following, then, are the final elements with their probable errors attached.

FINAL ELEMENTS

P	=	20·30 days	
e	=	·441 ±·017	
ω_1	=	219°·67 ±3°·15	
ω_2	=	39°·67 ±3°·15	
γ	=	−3·98 km./sec.	±0·65 km./sec.
K_1	=	45·71 km./sec.	±0·96 km./sec.
K_2	=	78·95 km./sec.	±1·90 km./sec.
T	=	J.D. 2,424,363·558	±0·109
$a_1 \sin i$	=	10,278,000 km.	
$a_2 \sin i$	=	17,753,000 km.	
$m_1 \sin^3 i$	=	1·87⊙	
$m_2 \sin^3 i$	=	1·08⊙	

The accompanying graph represents these elements, the continuous curve being that of component I. The residuals, shown in the Table of Observations, are scaled from these curves and give probable errors for a plate of ±3·1 and ±5·9 km. per sec. for components I and II respectively.

BOSS 5579

Fifty spectrograms out of sixty-five secured of this A-type binary are made the basis of the determination of its orbit. The component spectra are nearly, though not exactly, similar and show broad hydrogen lines with a fairly broad calcium λ3933 and very weak magnesium λ4481. The hydrogen lines are too broad to be properly resolved and the magnesium is so lacking in contrast that the results have to depend almost entirely on the calcium line. All observations are satisfied with a period 1·72897 days and a nearly circular orbit.

The star Boss 5579 (1900 $\alpha = 21^h\ 38^m{\cdot}4$, $\delta = +40°\ 38'$) whose visual magnitude is 5·48 and type A0 was announced as a spectroscopic binary by R. K. Young in these *Publications*, Volume I, page 175, from five plates taken here in 1918. The means of his measures and those of the writer appear in the table of observations. Sixty plates have since been secured but eleven of these were not measured as the component spectra were partially superposed rendering any resulting velocity meaningless. Four others, showing the lines as single, were measured but later rejected as a re-examination of the plates showed the lines to be broader than they should be when exactly superposed. Of the fifty plates used in the solution, eleven show the lines as single while on the remaining thirty-nine both component spectra are shown. Thus in effect the solution is based upon eighty-nine observations.

The spectra show fairly strong and broad hydrogen lines and the calcium line λ3933. The magnesium line λ4481 is decidedly lacking in contrast and it is only when the spectra are superposed that there is sufficient contrast for it to be measured at all satisfactorily. At such superpositions other weak metallic lines are glimpsed also. The hydrogen lines are rather broad to be satisfactorily resolved even at the maximum separation and consequently the measures for radial velocity are almost exclusively dependent upon the K-line of calcium. The plates as a whole are below the average quality of spectra secured here; it would have been better to have exposed all long enough for the K-region and to have used that line exclusively in the measurement. What is designated component I has its K-line slightly more intense and usually a little broader than the other, although the masses are approximately identical. Nearly all the plates were measured twice; the results are quoted in the table of observations to the nearest whole number only.

OBSERVATIONS OF BOSS 5579

Plate	Date	Julian Date	Phase	Component I			Component II		
				Velocity	Wt.	O-C	Velocity	Wt.	O-C
272	1918 June 28	2,421,773·945	1·513	−112	2	+12	+ 65	1	− 7
367	July 16	1,791·921	0·470	+100	1	+16	−127	1	+ 7
808	Oct. 30	1,897·664	0·746	+ 31	2	− 9	− 91	2	+ 1
1077	Dec. 20	1,948·532	1·474	−107	2	+22	+ 79	2	0
1127	" 23	1,951·537	1·021	− 35	1	+22			
11834	1925 July 4	4,336·905	0·410	+106	1	+26	− 84	1	+46
11848	" 6	4,338·964	0·740	.....	.....	.....	−130	1	−36
11876	" 10	4,342·971	1·289	−140	2	−10	+ 55	2	−25
11904	" 18	4,350·850	0·523	+ 67	3	−15	−142	3	− 8
11981	" 27	4,359·839	0·868	− 3	1	− 3			
11995	" 29	4,361·888	1·188	− 91	1	+19	+ 60	1	0

OBSERVATIONS OF BOSS 5579—*Concluded*

Plate	Date	Julian Date	Phase	Component I			Component II		
				Velocity	Wt.	O-C	Velocity	Wt.	O-C
12007	July 30	4,362·804	0·375	.....	.....	.....	−109	1	+17
12015	" 30	4,362·940	0·511	+ 71	1	−11	−112	1	+22
12046	Aug. 3	4,366·869	0·982	0	3	−42			
12089	" 7	4,370·878	1·533	−140	1	−21			
12094	" 12	4,375·792	1·260	−120	2	+ 6	+ 90	2	+14
12125	" 17	4,380·889	1·170	−110	2	− 4	+ 48	2	− 6
12133	" 19	4,382·721	1·273	−149	1	−22	+ 62	1	−16
12152	" 22	4,385·751	0·845	+ 21	1	+13			
12160	" 26	4,389·729	1·365	−145	2	− 9	+ 91	2	+ 6
12167	" 26	4,389·933	1·569	−137	2	−27	+ 63	2	+ 5
12185	" 29	4,392·783	0·961	− 18	2	+16			
12247	Sept. 11	4,405·670	0·016	− 18	2	+30			
12282	" 14	4,408·632	1·249	−103	1	+21	+ 80	1	+ 7
12289	" 14	4,408·884	1·501	−121	3	+ 4	+ 91	2	+16
12296	" 16	4,410·670	1·559	−119	2	− 7	+ 64	2	+ 3
12310	" 18	4,412·857	0·288	+ 54	1	− 2	− 96	1	+12
12340	" 21	4,415·838	1·540	−152	2	−35	+ 76	2	+10
12382	" 26	4,420·672	1·187	−124	1	−14	+ 43	1	−15
12430	Oct. 2	4,426·700	0·299	+ 55	2	− 4	−122	2	−10
12523	Sept. 12	4,436·614	1·568	− 89	1	+21			
12540	" 19	4,443·622	1·660	− 26					
12542	" 19	4,443·756	0·065	− 8	2	+20			
12562	" 22	4,446·674	1·254	−128	1	− 3	+ 77	1	+ 3
12566	" 24	4,448·632	1·483	−126	2	+ 1	+ 72	2	− 5
12568	" 30	4,454·618	0·553	+ 73	3	− 6	−155	3	−24
12621	Nov. 16	4,471·625	0·271	+ 64	1	+13	− 64	1	+39
12687	Dec. 2	4,487·681	0·766	+ 32	2	− 2	−111	1	−26
12711	" 28	4,513·551	0·701	+ 70	1	+18	− 92	1	+12
12740	1926 Jan. 5	4,521·587	0·092	− 15	2	− 1			
12743	" 7	4,523·567	0·343	+ 62	1	− 7	−141	1	−20
12751	" 11	4,527·569	0·888	− 40					
13664	July 2	4,699·863	0·285	+ 59	2	+ 5	−109	2	− 2
13680	" 3	4,700·912	1·334	−154	2	−19	+ 64	2	−19
13693	" 4	4,701·875	0·568	+ 70	2	− 7	−141	2	−11
13703	" 5	4,702·883	1·576	− 85	1	+22	+ 44	1	−12
13735	" 8	4,705·969	1·204	−131	2	−17	+ 69	2	+ 7
13746	" 9	4,706·867	0·373	+ 78	2	+ 3	−142	1	−16
13768	" 11	4,708·903	0·680	+ 36	2	−21	−106	2	+ 4
13801	" 14	4,714·952	1·542	−100	2	+16	+ 74	2	+ 8
13811	" 17	4,716·751	1·612	− 12					
13822	" 19	4,716·944	0·076	− 4	2	+16			
13863	" 26	4,723·958	0·174	+ 50	1	+30	− 44	1	+26
13898	" 31	4,728·983	0·012	− 10	2	+38			
13910	Aug. 1	2,424,729·900	0·929	− 20	2	+ 2			

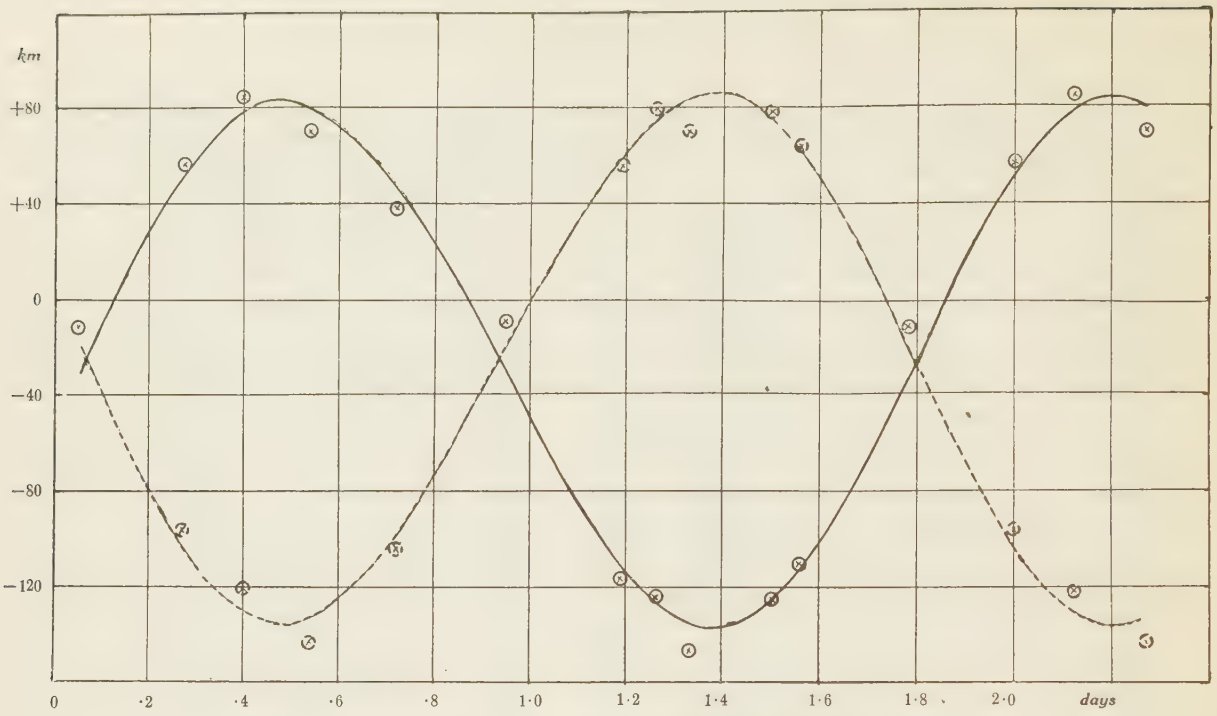


Fig. 3 Velocity Curves of Boss 5579 Showing Grouped Observations

Considerable difficulty was experienced in obtaining the period and for a long time one in the neighbourhood of 13 days was favoured. This, however, was not perfectly satisfactory and other shorter periods were sought for. Eventually the period of 1·73 days was found to be the most promising but owing to the somewhat scattered nature of the observations, no definite conclusion could be reached last year and the star was held over. The observations of the current season together with those of previous seasons, leave no doubt that the period of 1·72897 days, finally decided upon, is the correct one as every observation is satisfied within the errors of measurement.

Using this period and the time of periastron passage as J.D. 2,421,774·161 the phases of the observations are as given in the table. Here it may be stated that all dates are expressed in Greenwich Mean Time in the sense used prior to 1925. The observations after being weighted were grouped into 22 normal places, 11 representing each component.

NORMAL PLACES

—	Mean Phase	Mean Velocity	Wt.	Residual O-C	
				Prel.	Final
1	1·503	−124·8	1·2	+ 1·4	0·0
2	1·560	−110·8	0·8	+ 3·3	+ 1·5
3	0·052	− 11·0	0·4	+20·3	+20·2
4	0·272	+ 56·6	0·7	+ 2·0	+ 4·3
5	0·394	+ 84·8	0·5	+ 5·1	+ 7·0
6	0·542	+ 70·1	0·9	−11·6	−10·7
7	0·724	+ 38·3	0·7	− 9·3	− 7·8

NORMAL PLACES—*Concluded*

—	Mean Phase	Mean Velocity	Wt.	Residual O-C	
				Prel.	Final
8	0·946	− 9·3	0·4	+16·9	+20·7
9	1·187	−116·2	0·6	−10·4	− 6·0
10	1·259	−124·0	0·5	− 1·9	+ 1·3
11	1·329	−146·3	0·6	−14·2	−12·3
12	1·503	+ 77·9	0·9	− 0·3	+ 3·5
13	1·560	+ 63·7	0·7	− 2·4	+ 1·9
14	0·052	− 11·0	0·4	+ 5·7	+ 8·7
15	0·272	− 95·1	0·7	+ 7·5	+ 8·7
16	0·394	−120·6	0·5	+ 7·1	+ 8·8
17	0·542	−142·8	0·9	−13·1	−10·4
18	0·724	−103·9	0·7	− 8·3	− 6·4
19	0·946	− 9·3	0·4	+12·5	+11·7
20	1·187	+ 56·2	0·6	− 1·6	− 3·5
21	1·259	+ 79·8	0·5	+ 5·7	+ 4·9
22	1·329	+ 70·0	0·6	−14·1	−13·7

Preliminary elements were determined graphically as follows:—

$$
\begin{aligned}
P &= 1{\cdot}72897 \text{ days} \\
e &= {\cdot}05 \\
\omega_1 &= 255^\circ \\
\omega_2 &= 75^\circ \\
K_1 &= 110 \text{ km.} \\
K_2 &= 110 \text{ km.} \\
\gamma &= -20{\cdot}58 \\
T &= \text{J.D. } 2{,}421{,}774{\cdot}161
\end{aligned}
$$

The period was considered fixed as 1703 cycles have elapsed between the first and last observation. Furthermore, owing to the small value of the eccentricity, it was deemed expedient to determine T as accurately as could be done graphically and then consider it fixed. Otherwise the similarity of the coefficients having to do with T and ω would render the solution indeterminate.

In the observation equations built up according to the usual form* the following substitutions were made. The weights of each equation are as given in the Normal Places.

*Publications Dominion Observatory, Volume I, p. 327.

OBSERVATION EQUATIONS FOR BOSS 5579

1	1·000x	−0·929y	+0·000z	−0·896u	−0·448v	− 1·4	= 0
2	1·000	−0·819	+0·000	−1·015	−0·640	− 3·3	
3	1·000	−0·067	+0·000	+0·162	−1·046	−20·3	
4	1·000	+0·714	+0·000	+0·969	−0·735	− 2·0	
5	1·000	+0·942	+0·000	+0·337	−0·345	− 5·1	
6	1·000	+0·961	+0·000	−0·653	+0·177	+11·6	
7	1·000	+0·651	+0·000	−0·916	+0·700	+ 9·3	
8	1·000	−0·020	+0·000	+0·262	+0·952	−16·9	
9	1·000	−0·744	+0·000	+0·934	+0·634	+10·4	
10	1·000	−0·892	+0·000	+0·666	+0·429	+ 1·9	
11	1·000	−0·983	+0·000	+0·226	+0·194	+14·2	
12	1·000	+0·000	+0·929	+0·896	+0·448	+ 0·3	
13	1·000	+0·000	+0·819	+1·015	+0·640	+ 2·4	
14	1·000	+0·000	+0·067	−0·162	+1·046	− 5·7	
15	1·000	+0·000	−0·714	−0·969	+0·735	− 7·5	
16	1·000	+0·000	−0·942	−0·337	+0·345	− 7·1	
17	1·000	+0·000	−0·961	+0·653	+0·177	+13·1	
18	1·000	+0·000	−0·651	+0·916	−0·700	+ 8·3	
19	1·000	+0·000	+0·020	−0·262	−0·952	−12·5	
20	1·000	+0·000	+0·744	−0·934	−0·634	+ 1·6	
21	1·000	+0·000	+0·892	−0·666	−0·429	− 5·7	
22	1·000	+0·000	+0·983	−0·226	−0·194	+14·1	

These resulted in the following normal equations:—

14·200x	−0·993y	+0·634z	−0·371u	−0·199v	+19·550	= 0
	4·811	+0·000	+0·470	+0·292	+ 1·413	
		4·486	+0·138	+0·115	− 0·160	
			8·227	+0·711	+16·500	
				4·962	+10·129	

from which small corrections to the preliminary values of the elements were obtained as follows:—

$$\begin{aligned} \delta\gamma &= -1{\cdot}49 \text{ km./sec.} \\ \delta K_1 &= - \cdot 30 \text{ km./sec.} \\ \delta K_2 &= + \cdot 35 \text{ km./sec.} \\ \delta e &= - \cdot 017 \\ \delta\omega &= +1^\circ{\cdot}0 \end{aligned}$$

The value of Σpvv for the normal places was lessened by only 7 per cent, from 1157 to 1081, but no second solution was necessary as the differences between equation and ephemeris residuals did not exceed 0·2 km.

The final elements, with their probable errors are, then, as follows:—

P	=	1·72897 days	± ·00001 (estimated)
e	=	·033	± ·017
ω_1	=	256°·0	±1°·3
ω_2	=	76°·0	±1°·3
γ	=	−25·47 km./sec.	±1·44 km./sec.

K_1	=	109·70 km./sec.	±2·48 km./sec.
K_2	=	110·35 km./sec.	±2·55 km./sec.
T	=	J.D. 2,421,774·161	
$a_1 \sin i$	=	2,606,800 km.	
$a_2 \sin i$	=	2,622,100 km.	
$m_1 \sin^3 i$	=	$0 \cdot 96 \odot$	
$m_2 \sin^3 i$	=	$0 \cdot 95 \odot$	

The graph shown represents these final elements, the continuous curve being that for component I. The residuals given in the table of observations are scaled from this curve and give probable errors for components I and II respectively of ±9·9 and ±10·6 km./sec.

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TWO SPECTROSCOPIC BINARY ORBITS

BY R. M. PETRIE

H.R. 4535

ABSTRACT

The determination of the orbit of this star is based upon twenty-one single-prism spectrograms. The spectrum is of type A2 and the photographic magnitude is 6·01. The orbit is very nearly circular and the period is 2·7818 days. The projected major semi-axis and the mass function are both small.

The star H.R. 4535 (1900 $\alpha = 11^h\ 44^m{\cdot}1$, $\delta = +16°\ 48'$) is noted in the Harvard Revised Photometry as spectral type A2 and visual magnitude 5·95. Two spectrograms were secured in 1923 and these, on being measured by the writer this spring, showed definitely that the star was a binary, a difference of forty-five kms. in the two measures being present. Twenty-two spectra were obtained in the spring of 1926 and nineteen of them, together with the earlier observations, served as the observational data. Two of this year's plates were omitted on account of underexposure while one plate, although apparently normal, gave a discrepant velocity, being about 13 kms. too positive, and was rejected.

The spectrum of this star is characterized by a considerable number of solar lines, fairly sharp and admitting of good measurement, the strontium lines at λ4077 and λ4215 being particularly noticeable. The hydrogen lines are broad and the K-line of calcium of its usual strength for this type of star. A certain "fuzziness" in the edges of the lines would lead one to suspect the influence of the fainter component but a measureable set of lines was not obtained for it.

31406—1

Below are given the observations of the star in the usual tabular form.

OBSERVATIONS OF H.R. 4535

Plate Number	Date	Julian Day 2,420,000+	Phase	Velocity	Residuals O-C	Regions
8820	1923 April 11	3,521·762	0·762	−44·0	+0·8	1 = 23
8903	May 2	3,542·768	2·295	+ 1·3	+0·2	9 = 23
13359	1926 May 6	4,641·745	2·461	+ 5·9	0·0	1 = 23
13375	" 11	4,646·692	1·845	−20·1	+2·4	1 = 23
13391	" 13	4,648·754	1·125	−52·5	+1·7	1 = 23
13414	" 25	4,660·781	2·030	−14·2	−1·9	5 = 23
13418	" 28	4,663·701	2·163	− 5·6	−0·7	1 = 23
13422	" 29	4,664·728	0·408	−26·2	−6·0	9 = 23
13432	" 31	4,666·724	2·404	+ 3·7	−0·9	7 = 23
13441	June 2	4,668·752	1·650	−33·8	+1·6	1 = 23
13454	" 3	4,669·765	2·664	+ 8·0	+1·5	5 = 23
13465	" 6	4,672·785	0·120	− 1·2	−0·1	1 = 23
13487	" 10	4,676·744	1·297	−57·5	−6·0	9 = 23
13491	" 11	4,677·753	2·306	+ 3·5	+2·0	1 = 23
13500	" 12	4,678·732	0·503	−28·6	−1·1	1 = 23
13527	" 15	4,681·751	0·740	−43·2	+0·4	5 = 23
13546	" 18	4,684·716	0·924	−49·1	+2·5	1 = 23
13559	" 21	4,687·728	1·154	−56·0	−2·0	7 = 23
13576	" 24	4,690·725	1·369	−51·7	−2·5	7 = 23
13603	" 28	4,694·720	2·582	+ 7·5	+0·5	1 = 23
13638	July 1	4,697·722	0·021	+ 3·4	+0·3	9 = 23

The above observations led to the adoption of the following preliminary elements.

Preliminary Elements

$$P = 2{\cdot}7818 \text{ days}$$
$$e = 0{\cdot}050$$
$$\omega = 90°$$
$$\gamma = -23{\cdot}57 \text{ km. per sec.}$$
$$K = 30{\cdot}63 \text{ km. per sec.}$$
$$T = \text{J. D. } 2{,}423{,}521{\cdot}453$$

These elements were corrected by the method of least-squares, the observation equations being built up according to the method of Lehmann-Filhés. Each observation is treated separately and all are given equal weight. As the observations extend over three years and as the period is short, it was not felt necessary to include this element in the solution. The following transformations were made to preserve homogeneity:—

$$x = \delta\gamma$$
$$y = \delta K$$
$$z = K\delta e$$
$$u = K\delta\omega$$
$$v = \frac{K\mu}{(1-e^2)^{\frac{3}{2}}}\delta T$$

OBSERVATION EQUATIONS

1	1·000x	−0·127y	−0·254z	−1·042u	+1·091v	+1·100	= 0
2	1·000	−0·652	−1·007	−0·808	+0·816	−0·400	
3	1·000	−0·692	−1·018	−0·772	+0·775	−0·800	
4	1·000	−0·914	−0·750	−0·457	+0·424	−2·500	
5	1·000	−0·999	+0·090	−0·005	−0·045	−1·700	
6	1·000	−0·994	+0·219	+0·061	−0·110	+2·000	
7	1·000	−0·910	+0·748	+0·365	−0·398	+6·000	
8	1·000	−0·835	+0·907	+0·501	−0·522	+2·500	
9	1·000	−0·386	+0·697	+0·872	−0·839	−1·600	
10	1·000	+0·002	−0·004	+0·950	−0·902	−2·400	
11	1·000	+0·370	−0·672	+0·879	−0·845	+1·900	
12	1·000	+0·611	−0·947	+0·741	−0·729	+0·700	
13	1·000	+0·807	−0·940	+0·541	−0·556	−0·200	
14	1·000	+0·819	−0·927	+0·524	−0·542	−2·000	
15	1·000	+0·922	−0·709	+0·338	−0·373	+0·900	
16	1·000	+0·964	−0·509	+0·216	−0·259	±0·000	
17	1·000	+1·000	−0·008	−0·046	−0·004	−0·500	
18	1·000	+0·983	+0·368	−0·236	+0·189	−1·500	
19	1·000	+0·873	+0·862	−0·538	+0·511	−0·300	
20	1·000	+0·734	+1·013	−0·729	+0·726	+0·100	
21	1·000	+0·110	+0·228	−1·044	+1·095	+6·000	

The normal equations resulting from the above are, then:—

21·000x +	1·686y	−2·613z	+0·311u	−0·497v	+7·300	= 0
	12·305	−1·545	+1·232	−1·275	−5·605	
		10·410	−0·611	+0·587	+8·871	
			8·612	−8·634	−3·628	
				8·676	+3·815	

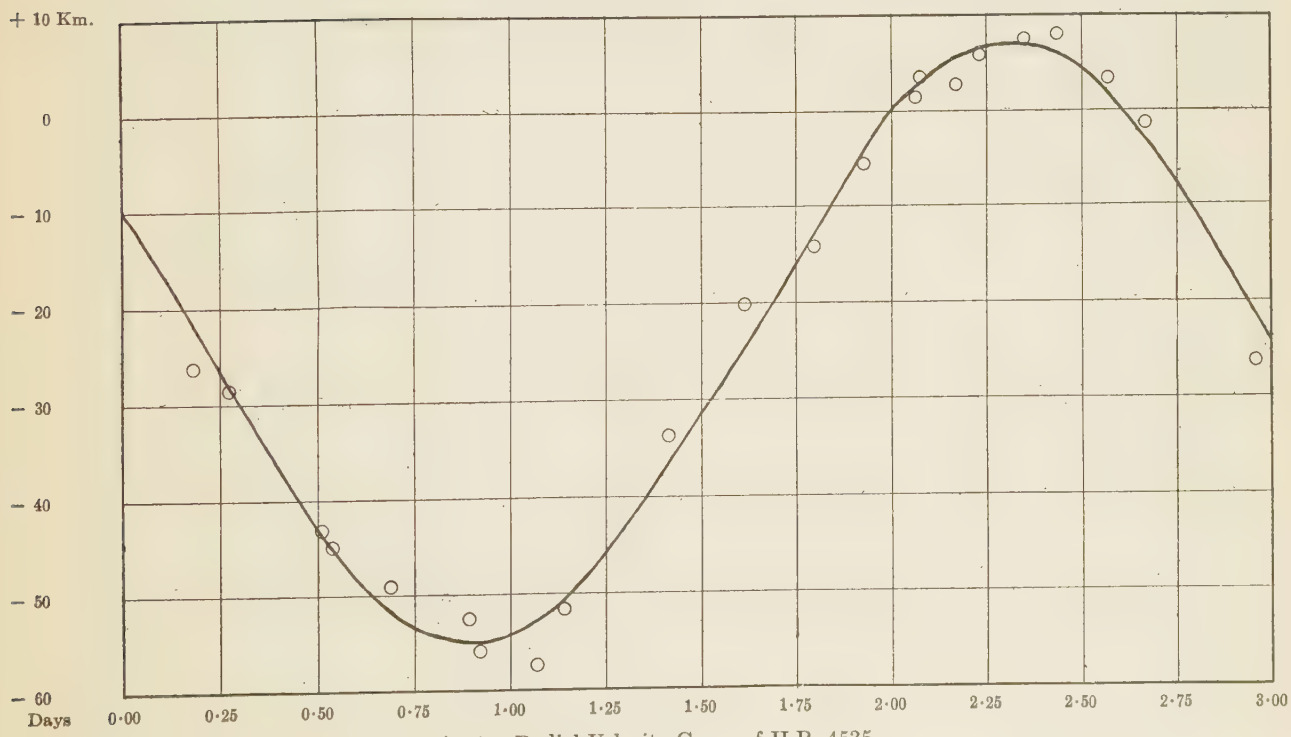

Fig. 1. Radial Velocity Curve of H.R. 4535.

The solution of these normal equations gave the succeeding corrections:—

$$\delta\gamma = -0{\cdot}64 \text{ km.}$$
$$\delta K = +0{\cdot}34 \text{ km.}$$
$$\delta e = -0{\cdot}032$$
$$\delta\omega = -28^\circ\ 15'$$
$$\delta T = -0{\cdot}222 \text{ days}$$

Below are given the final elements with their probable errors. The orbit, as will be seen from the elements, is nearly circular introducing a large probable error in the longitude of periastron passage; this uncertainty being necessarily felt in regard to the time of periastron passage also.

Final Elements

P	= 2·7818 days		
e	= 0·018	%	0·018
ω	= 61° 45′	%	23° 52′
γ	= −24·21 km.	%	0·40 km.
K	= 30·97 km.	%	0·50 km.
T	= J.D. 2,423,521·231	%	0·183 days
$a \sin i$	= 1,184,500 km.		
$\frac{m^3 \sin^3 i}{(m + m_1)^2}$	= 0·009⊙		

The sum of the squares of the residuals was lowered by the solution from 113·3 to 102·5, a reduction of about 10 per cent. The probable error of a single plate is ±1·5 kms.

The accompanying curve, Figure 1, represents the final elements with the individual observations plotted as circles.

BOSS 3555

ABSTRACT

The orbit of this spectroscopic binary whose visual magnitude is 5·91 and type F5 is based upon measures of both component spectra. The period is 36·04 days and eccentricity 0·490. The absolute magnitude has been previously determined here as 2·4.

The binary nature of Boss 3555 (1900 $\alpha = 13^h\ 42^m{\cdot}1$, $\delta = +26°\ 12'$) was announced by Dr. R. K. Young in the Publications of this observatory, Vol. I, No. 10. Four spectrograms were made in 1919 of which one showed the spectral lines distinctly doubled. Twenty-one plates were taken by various observers in 1925 and twenty-four more secured in 1926 since the writer undertook the determination of its orbital elements. The spectrograms were made with the single-prism spectrograph using a linear dispersion at Hγ of about 29 angstroms to the millimetre.

The star is of visual magnitude 5·91 and spectral type F5. The lines are sharp and the components of almost equal intensity so that it is sometimes difficult to distinguish between them. The orbit is fairly eccentric and with the dispersion used the separation of the components is measurable only about 40 per cent of the time. By using a slit slightly narrowed from its usual width of ·051 mm., however, a separation of about 80 kms. per sec. could be measured. Several plates were discarded owing to the partial superposition of the components, only those showing narrow and fairly well-defined lines being used to determine the crossing point of the two curves.

The table of observations showing all the measures used in forming normal places is given below. On account of the small separation, previously remarked, several plates were remeasured so that errors of measurement might be as small as possible. The residuals were scaled from a graph representing the final elements, no residuals being determined for points on the curve where the components are blended. With the exception of plate number 12828 all the spectrograms were measured on the micrometer engine, the number of lines used being noted; this plate showed very sharp lines and was measured on the Hartmann spectro-comparator, alternate regions between 1 and 23 being used. It might be here noted that the residual of that plate from an ephemeris constructed from the final elements was only 0·5 km., so that the above method of measuring was justified. The velocity of plate number 1875 is that given by Dr. Young in his announcement of the binary.

OBSERVATIONS OF BOSS 3555

Plate Number	Date	Julian Day 2,420,000+	Phase from T	Primary			Secondary		
				Vel.	O-C	Lines	Vel.	O-C	Lines
1780.....	1919 April 11	2,060·836	10·393	+41·7	+2·7	8	−40·4	−7·7	6
1875.....	" 23	2,072·801	22·358	+10·4					
11279.....	1925 March 7	4,216·994	4·151	+51·5	−3·6	12	−50·1	+2·4	9
11396.....	April 5	4,245·920	33·077	−54·8	−1·6	12	+75·8	−3·7	9
11438.....	" 8	4,248·845	36·002	+ 5·0	.....	15			
11450.....	" 9	4,249·836	0·953	+ 7·9	.....	13			
11477.....	" 13	4,253·827	4·944	+56·6	+1·5	11	−55·9	−3·3	7
11501.....	" 14	4,254·931	6·048	+53·4	+0·7	5	−52·4	−2·3	5

OBSERVATIONS OF BOSS 3555—*Concluded*

Plate Number	Date	Julian Day 2,420,000+	Phase from T	Primary			Secondary		
				Vel.	O-C	Lines	Vel.	O-C	Lines
11508.....	April 17	4,257·910	9·027	+48·1	+4·4	10	−41·0	−6·8	8
11608.....	May 12	4,282·777	33·894	−54·5	−3·1	10	+81·0	+3·7	9
12828.....	1926 Feb. 13	4,560·027	22·824	+ 6·0	.....	1=23			
13639.....	July 1	4,697·757	16·392	+16·7	.....	13			
13646.....	" 2	4,698·730	17·365	+11·8	.....	13			
13656.....	" 3	4,699·722	18·319	+14·0	.....	18			
13675.....	" 4	4,700·819	19·456	+12·6	.....	13			
13781.....	" 15	4,711·726	30·363	−37·8	+4·2	10	+65·8	−0·9	4
13809.....	" 20	4,716·713	35·350	−34·6	−4·1	9	+50·1	−2·4	6
13827.....	" 21	4,717·752	0·349	+ 1·9	.....	7			
13857.....	" 27	4,723·751	6·348	+46·8	−5·3	9	−47·7	+1·6	5
13866.....	" 28	4,724·708	7·305	+55·4	+6·2	11	−45·5	+0·5	6
13995.....	Aug. 19	4,746·689	29·286	−33·0	+3·2	9	+53·3	−5·3	9
14004.....	" 20	4,747·691	30·288	−39·9	+1·8	15	+59·3	−5·8	12
14006.....	" 21	4,748·677	31·274	−43·3	+3·2	24	+77·0	+5·2	18
14053.....	" 25	4,752·684	35·281	−33·9	−2·4	10	+52·9	−0·8	8

These observations led to the adoption of the following preliminary elements, a graphical method being used.

Preliminary Elements

$P = 36{\cdot}04$ days
$e = 0{\cdot}49$
$\omega_1 = 257°$
$\omega_2 = 77°$
$K_1 = 54{\cdot}82$ km. per sec.
$K_2 = 66{\cdot}46$ km. per sec.
$\gamma = +6{\cdot}70$ km. per sec.
$T = $ J.D. 2,422,014·403

In accordance with the usual practice it was decided to correct these elements by a least-squares solution. The observations were first combined, however, into normal places in order to reduce the mechanical labour of the solution. In the table are give the weighted mean phase and velocity of each group together with the preliminary and final residuals. The weights of each group are also appended. The individual weights of the plates were decided upon from three considerations, namely, the general quality of the plate, the number of lines measured on a plate and the number of times a plate was measured.

NORMAL PLACES

Mean Phase		Primary				Secondary			
Prel.	Final	Vel.	Wt.	O-C		Vel.	Wt.	O-C	
				Prel.	Final			Prel.	Final
0·586	0·506	+ 5·4	0·2	−1·2	−0·1	.....	0·2	−1·4	−2·3
4·547	4·467	+54·0	0·6	−1·5	−1·1	−53·0	0·6	−0·6	−0·3
6·567	6·487	+51·9	0·8	−0·4	+0·1	−48·5	0·8	+0·1	+0·3
9·710	9·630	+44·9	0·5	+2·5	+3·2	−40·7	0·5	−4·1	−4·3
19·005	18·925	+12·2	0·3	+2·8	+3·3	.....	0·2	+8·8	+8·6
29·286	29·206	−33·0	0·2	+3·7	+3·2	+53·3	0·2	−6·1	−5·2
30·325	30·245	−38·8	0·5	+3·7	+3·0	+62·6	0·5	−3·8	−2·7
31·274	31·194	−43·3	0·3	+4·3	+3·4	+77·0	0·3	+4·3	+5·6
33·485	33·405	−54·6	0·6	−0·7	−1·9	+78·4	0·6	−1·8	−0·3
35·315	35·235	−34·2	0·5	−2·1	−2·0	+51·5	0·5	−2·3	−2·2

The observation equations were then built up according to the formula of Lehmann-Filhés modified to deal with binaries showing both spectra*. The period was not included in the solution as it was felt that any slight change made in this element would not be significant and would not materially improve the agreement of the observations. The following usual transformations of the unknowns were then made:

*Publications D.O., Vol. I, p. 327.

$$x = \delta\gamma$$
$$y = \delta K_1$$
$$z = \delta K_2$$
$$u = 100\delta e$$
$$v = 100\delta\omega$$
$$w = \frac{100\mu}{(1-e^2)^{\frac{3}{2}}}\delta T = 26{\cdot}318\delta T$$

OBSERVATION EQUATIONS

1.....	+1·000x	−0·002y	+0·000z	+0·457u	+0·806v	−1·164w	+1·200	= 0
2.....	1·000	+0·890	+0·000	−0·110	+0·267	−0·004	+1·500	
3.....	1·000	+0·833	+0·000	−0·468	+0·079	+0·099	+0·400	
4.....	1·000	+0·651	+0·000	−0·571	−0·094	+0·130	−2·500	
5	1·000	+0·062	+0·000	−0·065	−0·278	+0·141	−2·100	
6.....	1·000	−0·792	+0·000	+0·630	−0·139	+0·211	−3·700	
7.....	1·000	−0·889	+0·000	+0·604	−0·082	+0·213	−3·200	
8.....	1·000	−0·898	+0·000	+0·680	−0·076	+0·257	−4·300	
9.....	1·000	−1·105	+0·000	−0·270	+0·316	−0·072	+0·700	
10.....	1·000	−0·708	+0·000	−0·692	+0·701	−0·923	+2·100	
11.....	1·000x	+0·000y	+0·002z	−0·554u	−0·978v	+1·412w	+1·400	
12.....	1·000	+0·000	−0·890	+0·133	−0·324	+0·005	+0·600	
13.....	1·000	+0·000	−0·833	+0·568	−0·096	−0·120	−0·100	
14.....	1·000	+0·000	−0·651	+0·692	+0·114	−0·158	+4·100	
15.....	1·000	+0·000	−0·062	+0·079	+0·338	−0·171	−9·600	
16.....	1·000	+0·000	+0·792	−0·764	+0·169	−0·256	+6·100	
17.....	1·000	+0·000	+0·889	−0·732	+0·100	−0·258	+3·200	
18.....	1·000	+0·000	+0·898	−0·825	+0·092	−0·312	−4·300	
19.....	1·000	+0·000	+1·105	+0·327	−0·383	+0·088	+1·800	
20.....	1·000	+0·000	+0·708	+0·839	−0·850	+1·119	+2·300	

From the observation equations resulted the normal equations which, when solved, yielded corrections to the preliminary elements.

NORMAL EQUATIONS

8·900x	−0·343y	+0·349z	+0·103u	−0·182v	+0·087w	+1·870	=	0
	2·989	+0·000	−0·685	−0·220	+0·287	+2·174		
		2·989	−0·831	−0·263	+0·346	+1·769		
			2·647	−0·729	+0·720	−1·139		
				1·276	−1·374	+0·008		
					1·909	−0·860		

$\delta\gamma$ = −0·20 km. per sec.
δK_1 = −0·81 km. per sec.
δK_2 = −0·64 km. per sec.
δe = ±0·000
$\delta\omega$ = +0·020 radians = 1°·15
δT = +0·080 days

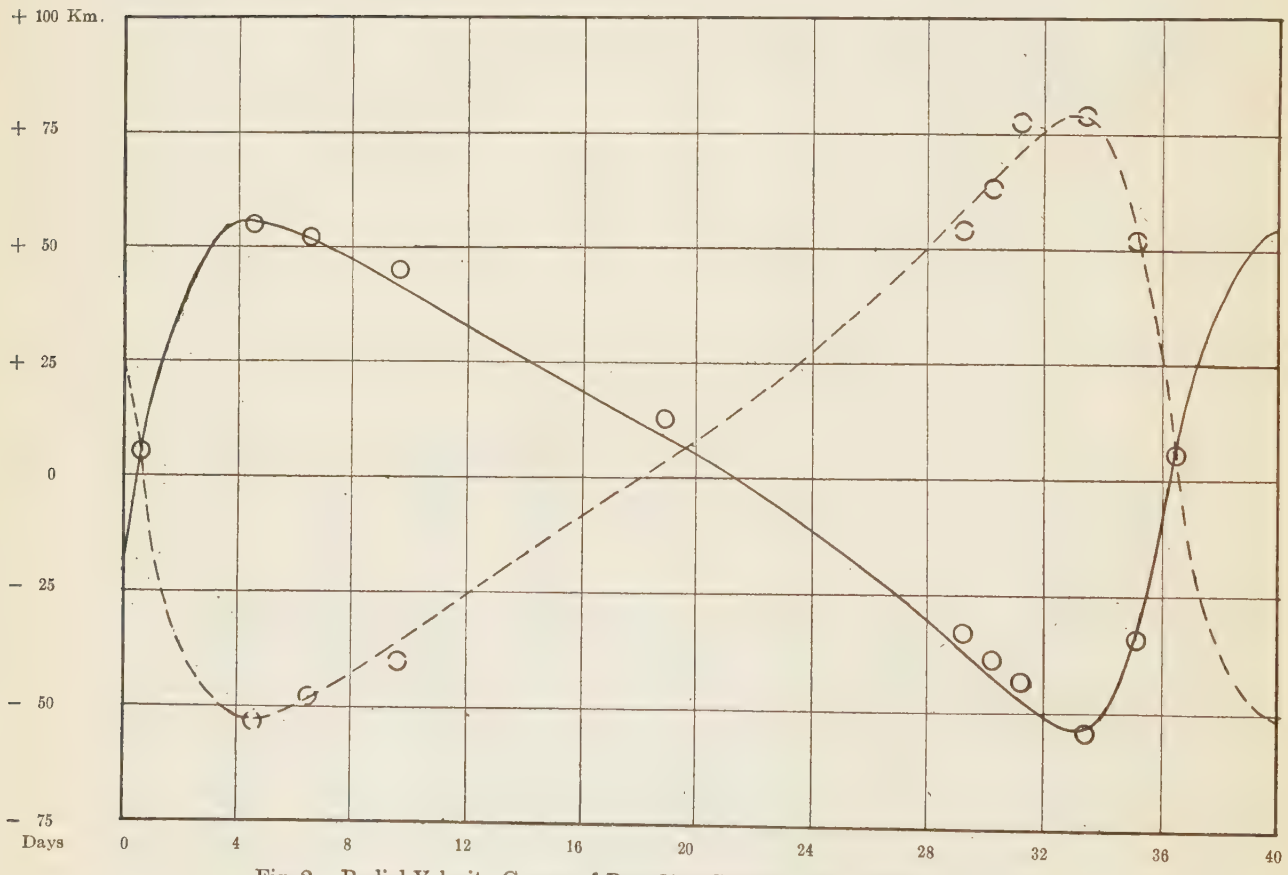

Fig. 2. Radial Velocity Curves of Boss 3555 Showing Grouped Observations.

The final elements with their probable errors are given below. The probable error of a single plate of weight unity is for the primary ±2·45 kms. per sec. and for the secondary ± 2·87 kms. per sec. The solution lowered the sum of the squares of the residuals from 68·8 to 60·8 for the primary and from 180·2 to 168·5 for the secondary.

Final Elements

P	= 36·04 days	
e	= 0·490	±0·012
ω_1	= 258° 09′	±1° 41′
ω_2	= 78° 09′	±1° 41′
K_1	= 54·01 km. per sec.	±0·94 km. per sec.
K_2	= 65·82 km. per sec.	±0·96 km. per sec.
γ	= +6·50 km. per sec.	±0·51 km. per sec.
T	= J.D. 2,422,014·483	±0·087 days
$a_1 \sin i$	= 23,333,000 km.	
$a_2 \sin i$	= 28,435,000 km.	
$m_1 \sin^3 i$	= 2·34 ⊙	
$m_2 \sin^3 i$	= 1·92 ⊙	

The radial velocity curves of the components are shown in Figure 2. The primary is indicated by the continuous curve and the secondary by the dotted line.

In presenting these two orbits as the principal results of a summer's work at this observatory the writer wishes to express his acknowledgements to the director and members of the observatory staff for assistance, and especially to Mr. W. E. Harper for guidance and help in the problems arising.

Dominion Astrophysical Observatory,
Victoria, B.C.
September, 1926.

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VICTORIA

Vol. III, No. 17

TWO K-TYPE SPECTROSCOPIC BINARIES

By W. E. Harper

33 PISCIUM

ABSTRACT

Fifteen single-prism spectrograms secured at Victoria in 1920 and 1926 serve to determine the orbit of this spectroscopic binary of type K0. The early observations of the Lick and Cape observatories fit in with the period of 72·93 days as herein determined. The semi-amplitude is 16·43 km./sec., the eccentricity ·272 and the probable error of a plate has the satisfactorily low value of ±0·8 km./sec.

The star 33 Piscium (1900 $\alpha = 0^h\ 00^m{\cdot}2$, $\delta = -6°\ 16'$), visual magnitude 4·68 and type K0 was announced as a spectroscopic binary in the *Lick Observatory Bulletin*, No. 199. Their first six plates showed but little range in the measures as they all happened to fall near the phase of maximum velocity, as shown by the table herein. The seventh plate, however, showed unmistakably the binary character of the star. Three plates were also made by the observers at the Cape Observatory in 1917, the data of these and the Lick plates being given for convenience of reference.

Three plates were obtained here in 1920 and measured by Dr. R. K. Young before leaving the Observatory; the rest of the work is due to the writer who took over the star at Young's suggestion. All the Victoria plates were made with the single-prism equipment, the dispersion at Hγ being about 29 angstroms per millimetre. The plates were measured on the spectro-comparator against Arcturus No. 2702 as a standard. As the plates are in many cases weaker in the violet than usual, by reason of the star's southern declination, it was customary to measure every region between λ4236 and λ4528 instead of alternate regions between λ4005 and λ4528 which is the usual procedure. The plate of September 8 is poorer than the average and should have been given slightly less weight than the others, but no appreciable error is introduced by considering them all of equal weight, as was done. Had this observation been weighted less the probable error of a plate would have been slightly reduced, but even as it stands now it has the exceptionally low value of ±0·8 km./sec.

33355

In the observations which follow, Greenwich Mean Time is used in the sense understood prior to 1925. The phases are reckoned from the periastron passage, finally adopted, using the period 72·93 days. This period, suggested by our own observations, satisfied reasonably well all the early observations and it was felt that no improvement would result by including it in the least-squares solution.

OBSERVATIONS AT OTHER OBSERVATORIES

Observatory	Date	Julian Date	Phase	Vel.	O-C
Lick	1905 Aug. 9	2,417,067·983	7·40	+10·5	+0·3
"	Oct. 19	7,138·805	5·30	+12·5	−0·2
"	1908 Aug. 4	8,158·964	4·43	+14·0	+0·6
"	Dec. 24	8,300·628	0·24	+13·8	+1·0
"	1909 Aug. 1	8,520·995	1·82	+13·7	−0·2
"	1910 Aug. 5	8,889·945	6·12	+15·3	+3·4
"	Oct. 24	2,418,969·739	12·98	+ 3·9	+1·5
Cape	1917 Nov. 10	2,421,543·360	33·08	−17·9	−1·7
"	Nov. 19	1,552·343	42·07	−20·1	−1·3
"	Dec. 4	1,567·304	57·03	−13·4	0·0

VICTORIA OBSERVATIONS

Plate	Date	Julian Date	Phase	Vel.	O-C
4705	1920 July 25	2,422,531·965	1·64	+14·6	+0·7
5134	Sept. 29	2,597·866	67·54	+ 5·1	+1·5
5247	Oct. 21	2,619·729	16·47	− 2·6	+0·2
13823	1926 July 19	4,716·966	71·67	+11·5	+0·2
13957	Aug. 5	4,733·986	15·76	− 1·8	−0·1
14003	" 18	4,746·976	28·75	−15·0	−1·1
14015	" 20	4,748·992	30·76	−13·3	+1·7
14099	" 30	4,758·940	40·71	−20·0	−1·4
14158	Sept. 8	4,767·853	49·62	−15·7	+2·3
14197	" 11	4,770·874	52·64	−17·8	−1·3
14249	" 19	4,778·855	60·63	−10·1	−1·0
14260	" 22	4,781·854	63·62	− 3·6	+0·6
14290	" 25	4,784·846	66·62	+ 0·4	−1·3
14318	Oct. 4	4,793·817	2·66	+12·9	−1·1
14327	" 11	4,800·795	9·63	+ 7·8	+0·5

NORMAL PLACES

——	Mean Phase		Vel.	Wt.	O-C	
	Prel.	Final			Prel.	Final
1	3·30	2·15	+13·8	2	−0·2	−0·2
2	10·78	9·63	+ 7·8	1	−0·1	+0·5
3	17·26	16·11	− 2·2	2	−1·2	−0·3
4	30·90	29·75	−14·1	2	+0·4	+0·5
5	41·86	40·71	−20·0	1	−0·5	−1·4
6	52·28	51·13	−16·8	2	+1·9	+0·6
7	61·78	60·63	−10·1	1	−0·6	−1·0
8	64·77	63·62	− 3·6	1	+0·5	+0·6
9	67·77	66·62	+ 0·4	1	−1·8	−1·3
10	68·69	67·54	+ 5·1	1	+0·9	+1·5
11	72·82	71·67	+11·5	1	−0·1	+0·2

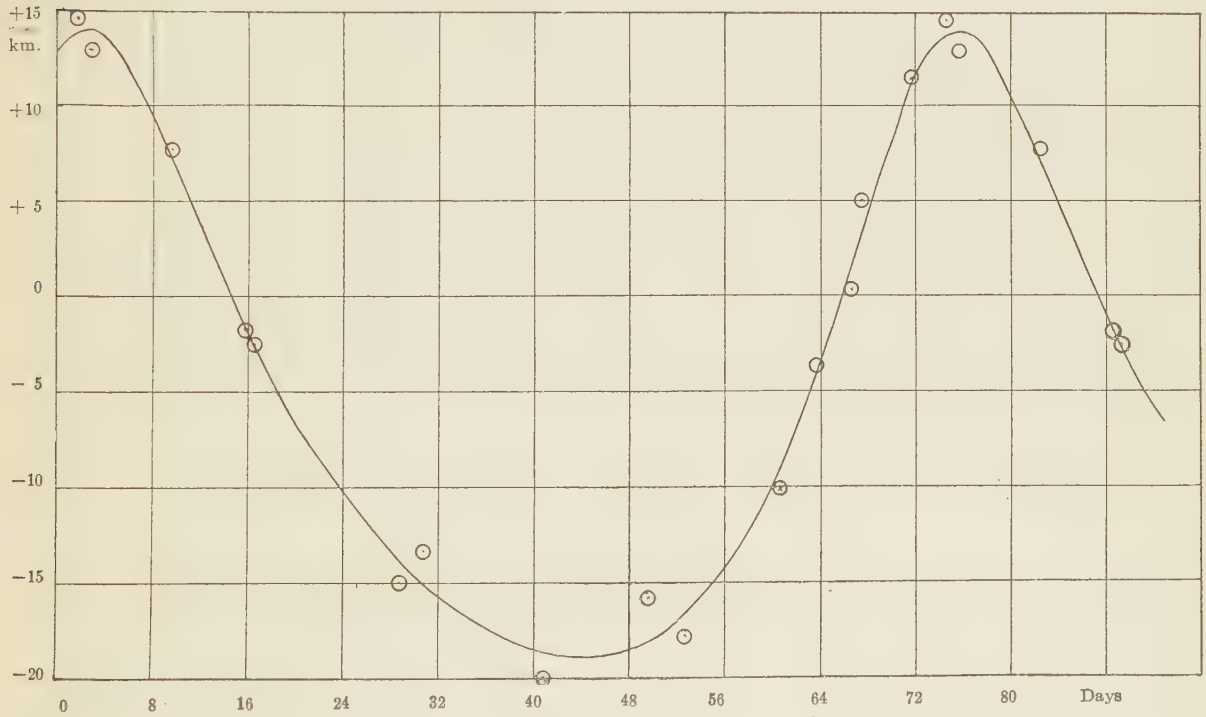

Fig 1. Velocity Curve of 33 Piscium, Showing Individual Observations.

Preliminary Elements

P = 72·93 days
e = 0·25
ω = 330°
γ = −6·68 km./sec.
K = 17·0 km./sec.
T = J.D. 2,422,529·180

These preliminary elements were obtained in the usual graphical manner and then observation equations were built up connecting the residuals for the normal places with the elements. In these equations the following substitutions were made:—

$$\begin{aligned} x &= \delta\gamma \\ y &= \delta K \\ z &= K\delta e \\ u &= -K\delta\omega \\ v &= +16{\cdot}135\ \delta T \end{aligned}$$

OBSERVATION EQUATIONS

1	1·000x	+1·215y	+0·901z	−0·167u	−0·063v	+0·2 = 0
2	1·000	+0·855	−0·785	+0·644	+0·835	+0·1
3	1·000	+0·333	−0·984	+0·868	+0·806	+1·2
4	1·000	−0·463	+0·458	+0·609	+0·425	−0·4
5	1·000	−0·757	+0·990	+0·107	+0·134	+0·5
6	1·000	−0·707	+0·265	−0·509	−0·276	−1·9
7	1·000	−0·168	−1·120	−1·048	−0·983	+0·6
8	1·000	+0·150	−1·149	−1·123	−1·230	−0·5
9	1·000	+0·520	−0·628	−1·078	−1·338	+1·8
10	1·000	+0·637	−0·361	−1·032	−1·315	−0·9
11	1·000	+1·073	+0·844	−0·640	−0·804	+0·1

These resulted in the following normal equations:—

$$\begin{array}{rrrrrr} 15{\cdot}000x & +3{\cdot}066y & -0{\cdot}929z & -2{\cdot}568u & -2{\cdot}917v & -0{\cdot}100 = 0 \\ & 7{\cdot}784 & -0{\cdot}320 & -1{\cdot}099 & -1{\cdot}423 & +4{\cdot}343 \\ & & 9{\cdot}526 & +0{\cdot}853 & +1{\cdot}171 & -3{\cdot}777 \\ & & & 8{\cdot}245 & +8{\cdot}496 & +2{\cdot}439 \\ & & & & 9{\cdot}179 & +1{\cdot}490 \end{array}$$

from which the following corrections were obtained:—

$$\begin{aligned} \delta\gamma &= +0{\cdot}12 \text{ km./sec.} \\ \delta K &= -0{\cdot}57 \text{ km./sec.} \\ \delta e &= +0{\cdot}022 \\ \delta\omega &= +7°{\cdot}71 \\ \delta T &= +1{\cdot}150 \text{ days} \end{aligned}$$

The value of Σpvv for the normal places was reduced from 15·43 to 9·03, or about 35 per cent.

The following, then, are the final values of the elements with their corresponding probable errors attached:—

FINAL ELEMENTS

$$\begin{aligned} P &= 72{\cdot}93 \text{ days} \\ e &= 0{\cdot}272 \quad \pm 0{\cdot}017 \\ \omega &= 337°{\cdot}71 \quad \pm 4°{\cdot}60 \\ \gamma &= -6{\cdot}56 \text{ km./sec.} \quad \pm 0{\cdot}23 \text{ km./sec.} \\ K &= 16{\cdot}43 \text{ km./sec.} \quad \pm 0{\cdot}31 \text{ km./sec.} \\ T &= \text{J.D. } 2{,}422{,}530{\cdot}330 \quad \pm 0{\cdot}809 \text{ day} \\ a \sin i &= 15{,}856{,}000 \text{ km.} \end{aligned}$$

The graph shown, Figure 1, represents these final elements.

71 AQUILAE

ABSTRACT

Twenty-six spectrograms secured at Victoria during the years 1920 to 1926 are used to determine the orbit of this binary, announced twenty-one years ago from the Lick Observatory. The early observations of the Lick, Bonn and Cape observatories fit in with the period of 205 days as determined here. The range is small, the semi-amplitude being 9·78 km./sec., but as the star is of K-type the measures are reliable and the orbit is satisfactorily determined. The probable error of a plate is ±1·0 km. per second.

The star 71 Aquilae (1900 $\alpha = 20^h\ 33^m{\cdot}2$, $\delta = -1°\ 27'$) visual magnitude 4·51 and type K0, was announced as a spectroscopic binary by Curtis from the Lick Observatory in *Lick Observatory Bulletin*, Volume III, page 86. The third plate showed a definite variation in the radial velocity. Their five plates together with three taken at Bonn and three also from the Cape Observatory appear in the table of early observations. Aside from slight systematic differences the residuals, as computed from the Victoria elements, are satisfactory for all three observatories.

Of the twenty-six plates obtained at Victoria between the years 1920 and 1926 fifteen were secured by Dr. R. K. Young and these, with four others, were measured by him before leaving this Observatory. At his suggestion this spring the writer undertook to secure the additional plates that were necessary to determine the period and other elements of the orbit. Four of his plates were remeasured by the writer, the results agreeing within 0·5 km. and the means of the two have been used. Another plate, number 8282, is missing from the collection, otherwise it would have been remeasured as it gives a large residual. From the limited number of regions measured on it by Young it is evidently a weak plate and accordingly has been given half weight.

The plates were all taken with the single-prism equipment giving a dispersion at Hγ of 29 angstroms to the millimetre. They were measured on the spectrocomparator against Arcturus No. 2702 as a standard and in general alternate regions from λ4005 to λ4528, or twelve in all, were measured.

In the observations which follow Greenwich Mean Time is used in the sense understood prior to 1925. The decimal of a day is assumed for the Lick observations.

OBSERVATIONS OF 71 AQUILAE AT OTHER OBSERVATORIES

Observatory	Date	Julian Date	Phase	Vel.	O-C
Lick	1900 June 18	2,415,189·8	53·2	− 2	−0·5
"	July 10	5,211·8	75·2	− 5	+2·3
"	1903 Sept. 22	6,380·8	14·2	+ 3·0	−1·5
"	1904 Aug. 7	6,700·8	129·2	−12·7	+2·2
"	" 30	6,723·8	152·2	−11·3	+1·9
Bonn	1910 Sept. 18	8,933·4	106·8	− 9·1	+4·2
"	" 21	8,936·4	109·8	−10·1	+3·6
"	1911 Sept. 1	9,281·4	44·8	− 1·0	−1·5
Cape	1917 Sept. 19	1,491·4	204·8	+ 2·5	0·0
"	1918 Aug. 21	1,827·4	130·8	−13·7	+1·2
"	" 23	2,421,829·3	132·7	−15·0	−0·2

VICTORIA OBSERVATIONS OF 71 AQUILAE

Plate	Date	Julian Date	Phase	Vel.	Wt.	O-C
4516	1920 June 30	2,422,506·899	195·35	+ 1·5	1	+1·8
4697	July 25	2,531·827	15·28	+ 4·2	1	−0·3
5026	Sept. 3	2,571·739	55·19	− 1·2	1	+1·0
5244	Oct. 21	2,619·624	103·07	−10·5	1	+2·3
6007	1921 May 3	2,815·992	94·44	−12·2	1	−0·8
6210	July 10	2,881·886	160·34	−11·5	1	+0·1
6562	Sept. 14	2,947·715	21·17	+ 4·1	1	−0·4
6827	Nov. 8	3,002·591	76·04	− 9·8	1	−2·2
7637	1922 June 7	3,213·956	82·41	−10·1	1	−1·1
8010	Aug. 28	3,295·756	164·21	−11·6	1	−1·0
8212	Oct. 9	3,337·670	1·12	+ 5·0	1	+2·3
8282	Nov. 2	3,361·578	25·03	+ 8·8	½	+4·6
8457	Dec. 1	3,390·563	54·01	− 0·8	1	+1·1
9514	1923 Oct. 11	3,704·649	163·10	−10·5	1	+0·4
10140	1924 June 22	3,959·927	8·38	+ 5·5	½	+1·6
10218	July 3	3,970·885	19·33	+ 1·4	1	−3·2
10235	" 6	3,973·921	22·37	+ 3·5	1	−0·9
10291	" 13	3,980·875	29·33	+ 5·4	1	+1·8
10326	" 20	3,987·892	36·34	+ 2·2	1	−0·3
13748	1926 July 9	4,706·901	140·35	−14·0	1	+0·5
13915	Aug. 2	4,730·859	164·31	−11·3	1	−0·7
13998	" 18	4,746·813	180·26	− 5·3	1	+0·4
14091	" 30	4,758·706	192·16	− 1·7	1	−0·3
14092	" 30	4,758·718	192·17	− 2·3	1	−0·9
14148	Sept. 6	4,765·750	199·20	− 1·0	½	−2·0
14206	" 13	2,424,772·749	1·20	+ 2·6	1	−0·1

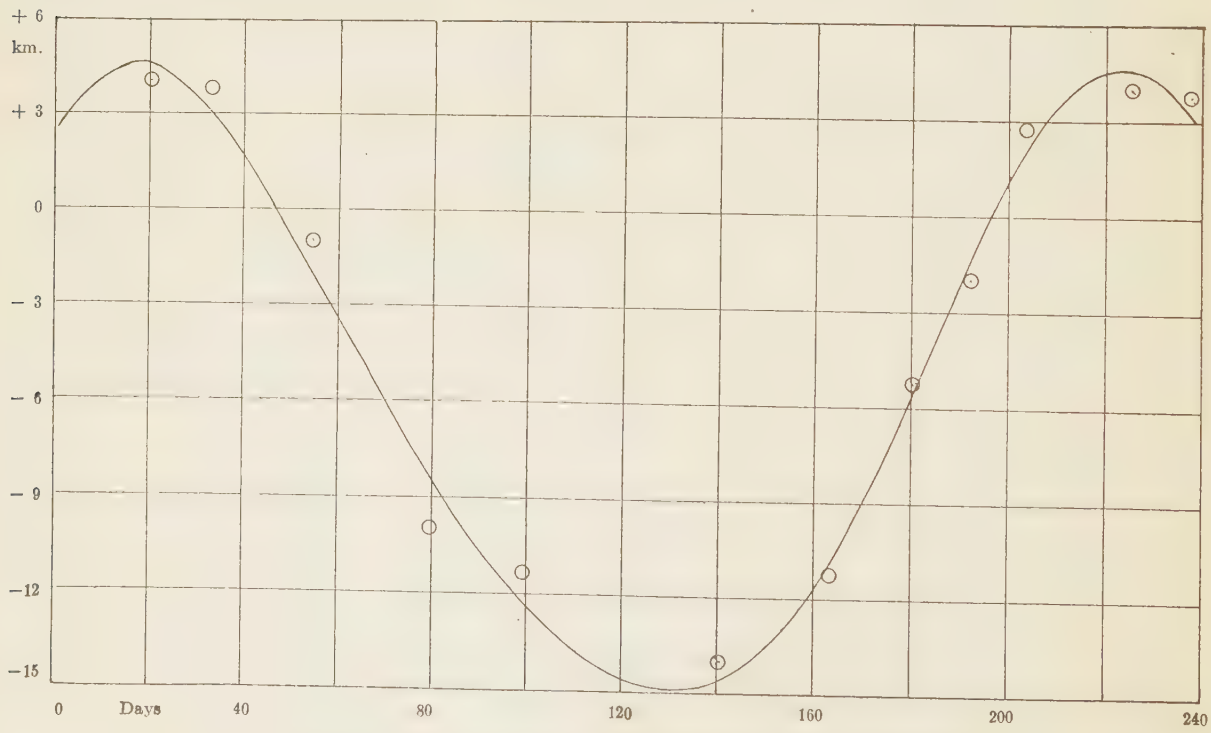

Fig. 2. Radial Velocity Curve of 71 Aquilæ Showing Grouped Observations.

With the aid of the early observations the period was determined by the writer as 205·0 days and this value is considered as definite without any recourse to least-squares. The Victoria observations were grouped according to phase into ten normal places and a set of preliminary elements obtained graphically. No further use was made of the early observations.

NORMAL PLACES

	Mean Phase		Velocity	Wt.	O-C	
	Prel.	Final			Prel.	Final
1	49·81	54·60	− 1·00	2	+0·98	+1·01
2	74·44	79·23	− 9·95	2	−1·50	−1·64
3	93·96	98·75	−11·35	2	+1·06	+0·83
4	135·56	140·35	−14·00	1	+0·39	+0·54
5	158·20	162·99	−11·22	4	−0·55	−0·23
6	175·47	180·26	− 5·30	1	+0·37	+0·38
7	187·38	192·17	− 2·00	2	−0·24	−0·61
8	198·70	203·49	+ 2·71	4	+1·23	+0·56
9	15·36	20·15	+ 4·00	4½	−0·09	−0·61
10	28·04	32·83	+ 3·80	2	+0·86	+0·67

Preliminary Elements

$P = 205{\cdot}0$ days
$e = 0{\cdot}10$
$\omega = 330°$
$\gamma = -6{\cdot}22$ km./sec.
$K = 9{\cdot}5$ km./sec.
$T =$ J.D. 2,422,316·34

In the observation equations, built up according to the usual Lehmann-Filhés form, the following substitutions were made:—

$x = \delta\gamma$
$y = \delta K$
$z = K\delta e$
$u = -K\delta\omega$
$v = \cdot 2956\,\delta T$

OBSERVATION EQUATIONS FOR 71 AQUILAE

1	1·000x	+0·447y	−0·982z	+0·883u	+0·903v	−0·98 = 0
2	1·000	−0·234	−0·349	+0·897	+0·811	+1·50
3	1·000	−0·651	+0·588	+0·624	+0·551	−1·06
4	1·000	−0·859	+0·385	−0·376	−0·284	−0·39
5	1·000	−0·468	−0·806	−0·882	−0·822	+0·55
6	1·000	+0·061	−0·955	−1·050	−1·098	−0·37
7	1·000	+0·470	−0·316	−0·974	−1·076	+0·24
8	1·000	+0·811	+0·523	−0·740	−0·830	−1·23
9	1·000	+1·086	+0·809	−0·001	+0·058	+0·09
10	1·000	+0·965	+0·018	+0·429	+0·530	−0·86

These resulted in the following normal equations:—

$$\begin{aligned}
24{\cdot}500x + 7{\cdot}455y - 0{\cdot}144z - 4{\cdot}200u - 4{\cdot}291v - 5{\cdot}395 &= 0 \\
13{\cdot}218 + 5{\cdot}028 - 1{\cdot}027 - 0{\cdot}972 - 5{\cdot}900 & \\
10{\cdot}763 + 1{\cdot}155 + 1{\cdot}073 - 4{\cdot}367 & \\
12{\cdot}757 + 12{\cdot}906 + 0{\cdot}667 & \\
13{\cdot}192 + 0{\cdot}883 &
\end{aligned}$$

from which the following corrections were obtained:—

$$\begin{aligned}
\delta\gamma &= +0{\cdot}13 \text{ km./sec.} \\
\delta K &= +0{\cdot}28 \text{ km./sec.} \\
\delta e &= +0{\cdot}028 \\
\delta\omega &= -0^\circ{\cdot}57 \\
\delta T &= -4{\cdot}79 \text{ days}
\end{aligned}$$

The value of Σpvv for the normal places was reduced from 17·83 to 13·97, or about 22 per cent, and all differences between equation and ephemeris residuals were less than 0·1 km.

The probable error of a plate obtained from the last two columns of the table of Victoria observations is ±1·0 km. per sec., a value very satisfactory for single-prism dispersion.

The following are the final elements with their probable errors attached:—

Final Elements

P	=	205·0 days	
e	=	0·128	±0·042
ω	=	321°·43	±18°·88
γ	=	−6·09 km./sec.	±0·26 km./sec.
K	=	9·78 km./sec.	±0·39 km./sec.
T	=	J.D. 2,422,311·55	±10·40 days
$a \sin i$	=	27,347,000 km.	

The graph shown, Figure 2, represents these elements with the observations as grouped.

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Victoria, B.C.,
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THE ORBITS OF TWO SPECTROSCOPIC BINARIES

BY S. N. HILL

ABSTRACTS

Kappa Draconis.—An orbit of the spectroscopic binary star Kappa Draconis, H.D. 109387, mag. 3·88, type B5p, was published by Baker from observations at the Detroit Observatory on the basis of a period of 8·986 days. Some observations at Victoria showed marked disagreement with this orbit and consequently the star was re-observed here and a new orbit with a period of 0·89038 days, $e=0·186$, $K=18·87$ km., $\gamma=-11·43$ km., was obtained from 38 plates. As the probable error per plate has the low value of $\pm 1·7$ km. per sec. for this rather diffuse lined B star, there can be no reasonable doubt of the correctness of the new orbit.

H.D. 214240.—The first plate obtained showed double lines and the orbit was determined from 32 plates. The Henry Draper Catalogue gives the spectral type as B3, visual magnitude 6·20. From an investigation of the spectrum the type of the primary is estimated as B2·5 and that of the secondary as B8. The lines in the secondary are faint and could only be measured with any degree of accuracy at the nodes where the separation is about 200 km. The star has a high eccentricity, 0·253. The minimum masses are 6·01 and 3·87 times the sum. From probable estimates of density and calculated values of surface brightness it seems certain that this star is at least 1,300 light years distant.

KAPPA DRACONIS

INTRODUCTION

The spectroscopic binary κ Draconis has an interesting observational history as it has been observed and discussed at Harvard[1], at Mount Hamilton[2] and at Ann Arbor[3], as well as here. It is of class B5p with hydrogen emission and the discussion at Harvard and Lick mainly dealt with the character of the spectrum and the peculiar and possibly variable nature of the complex emission and absorption detail at the Balmer series of hydrogen. The discussion at Ann Arbor, however, was a full treatment of the problem not only in regard to the hydrogen lines but also of the other absorption lines and of Ca K. Briefly, the measures of the hydrogen lines indicated a long period change of about four years over a range of 12 km. The behaviour of the K-line, which is not well defined, appeared to follow the hydrogen lines. The broad absorption and emission lines were

[1] The references will be found on p. 357.

shown to oscillate in a period of 8·986 days with a semi-amplitude of 15·7 km. and an eccentricity of 0·23.

Unfortunately Baker's conclusions are not confirmed by the Victoria observations which show a short period oscillation of 0·89038 days, semi-amplitude of 18·87 km. and eccentricity of 0·186. Further, the broad absorption lines, the narrow hydrogen absorption and the K-line all oscillate in the same period and move in the same orbit in direct contradiction to Baker's results. In view of this difference in results, a statement of how the star came to be observed at Victoria seems in order. An observing programme of all the B-type stars from B0 to B5, brighter than 7·5 mag. and north of declination −11° was undertaken by the director in 1923 and 1924, with the collaboration of J. A. Pearce in the latter year. Although all B stars were placed on this programme, it was not proposed to observe any for which satisfactory velocities were already available, except to secure one or two spectra for the purpose of revision of the classification. The star κ Draconis, which came under this heading, was bright and was, moreover, in a region of the sky where B stars are scarce. Four spectra were obtained in 1923 and at the request of the Director, these were measured by the writer without any thought of checking Baker's work. The measures, however, deviated so greatly from Baker's curve as to justify obtaining more spectra on fine grained plates for the purpose of clearing up the discrepancy. The work is given in sufficient detail below to enable the Ann Arbor and Victoria observations to be directly compared and their value adjudged. It is of course possible, from the previously observed changes in the spectrum, that the differences may be ascribed to a radical change in its character but as so great a change seems unlikely the reader must decide from the internal evidence of the observations which treatment is to be preferred.

The Victoria Observations

The star κ Draconis, H.D. 109387, R.A. $12^h\ 29^m{\cdot}2$, Dec. +70° 20′, viz. mag. 3·88, spectral type B5p, has a spectrum of rather diffuse, but, as seen below in the detailed table of line velocities, apparently accurately measurable helium lines, with Mg 4481 and C4267 of about the same character as the helium lines. The K-line of calcium is also generally weak and diffuse and only in two or three plates was it well defined. The most striking features of the spectrum are the Balmer lines of hydrogen which have complex structure of emission and absorption. At Hβ there is a broad absorption band about 12 A wide while superposed centrally on this is a sharp emission band about 6 A wide with a narrow sharp absorption line in its centre. At Hγ neither the broad absorption which is about 9 A wide, nor the central emission, about 5 A wide, are so strong or well defined as in Hβ but the central reversal is strong and sharp though wider than in Hβ. At Hδ and Hϵ the absorption is broad, the central emission can scarcely be seen although the central reversal fairly sharp and well measurable is an indication of its probable presence. The hydrogen spectrum as observed at Ann Arbor was apparently similar although the central narrow absorption at Hβ disappeared on the later plates. Merrill at Lick observed this central absorption on a plate of Feb. 26, 1912 although not visible on plates of the previous year, and as it was not noted at Harvard, the hydrogen spectrum is probably variable in character.

After the four plates of 1923-24 were measured and the discrepancy between them and Baker's velocity curve noted, 34 spectra of κ Draconis were obtained in the spring and summer of 1926 by different observers whose kindness is hereby gratefully acknowledged. These plates were all carefully measured by the writer. The data of observations and measurement of these plates are given in the table of observations, Table I below. The first column contains the serial number of the plate, the second the date, the third the Julian Date, the fourth the phase reckoned from Julian Day 2,424,650·0, the fifth the velocity, the sixth the number of lines measured and the seventh the residual O–C between the measures and the final orbit.

TABLE I—VICTORIA OBSERVATIONS OF KAPPA DRACONIS

Plate Number	Date	Julian Day 2,420,000+	Phase from J.D. 2,424,650·000	Velocity	Lines Measured	Residuals O–C
8927	1923 May 6	3,546·821	0·002	−15·7	9	+1·2
9781	1924 Mar. 6	3,866·845	0·379	−15·5	7	−0·5
9976	May 18	3,924·695	0·355	−18·4	8	+1·1
10026	" 28	3,934·756	0·622	+ 5·7	9	−1·1
12975	1926 Mar. 5	4,579·975	0·315	−26·1	12	−1·3
13399	May 17	4,652·840	0·169	−28·4	10	−0·1
13401	" 19	4,654·788	0·336	−21·8	9	+0·2
13402	" 20	4,655·713	0·371	−20·4	9	−3·6
13406	" 23	4,658·743	0·730	− 0·7	7	+0·8
13408	" 24	4,659·772	0·868	−20·3	9	−5·3
13413	" 25	4,660·756	0·072	−20·1	9	+2·3
13419	" 28	4,663·727	0·371	−18·3	10	−1·5
13421	" 29	4,664·708	0·462	− 2·0	9	−2·0
13425	" 30	4,665·780	0·644	+ 6·0	11	+0·5
13435	" 31	4,666·825	0·798	− 6·7	8	+1·4
13444	June 2	4,668·807	0·109	−25·2	10	−0·2
13452	" 3	4,669·698	0·110	−24·9	6	+0·2
13461	" 5	4,671·728	0·359	−24·1	7	+4·8
13468	" 6	4,672·908	0·649	+ 7·4	9	+2·4
13526	" 15	4,681·710	0·547	+ 9·8	8	+1·8
13528	" 15	4,681·774	0·611	+ 4·1	9	−3·4
13531	" 15	4,681·835	0·672	+ 2·1	10	−1·2
13534	" 15	4,681·892	0·729	− 0·2	6	+1·3
13537	" 15	4,681·945	0·782	− 4·0	10	+2·6
13540	" 15	4,681·983	0·820	−11·5	8	−1·5
13565	" 21	4,687·826	0·430	− 3·4	10	+2·6
13587	" 25	4,691·787	0·830	−11·9	11	−0·9
13590	" 25	4,691·841	0·884	−16·4	10	−0·4
13600	" 26	4,692·914	0·176	−28·7	8	−0·2
13602	" 26	4,692·963	0·225	−27·7	12	+1·7
13605	" 28	4,694·772	0·253	−28·1	8	+1·0
13609	" 28	4,694·881	0·362	−20·2	9	+8·0
13611	" 28	4,694·904	0·385	−10·6	12	+3·6
13627	" 29	4,695·928	0·519	+ 6·5	8	−0·2
13641	July 1	4,697·806	0·616	+ 5·8	9	−1·3
13674	" 4	4,700·798	0·046	−22·9	9	−2·1
13691	" 5	4,701·834	0·192	−27·8	8	+1·5
13709	" 8	4,704·785	0·472	+ 5·6	8	+4·0

The measures were all carefully made, the number of lines measured varying between 6 and 12, all lines well measurable including the hydrogen, helium, magnesium, carbon and calcium being used. In the hydrogen lines the central sharp absorption reversal was measured and not the emission which has apparently the same position but is not easily measurable even at Hβ. In order to show that the differences found by Baker between the velocities of the hydrogen lines and of 4481 Mg+ and 4471 He, the only other lines he measured, do not exist on the Victoria plates the measures of the individual lines in each plate with the weighted mean velocity all reduced to the sun are given in Table II below.

TABLE II—LINE VELOCITIES IN KAPPA DRACONIS

Plate / λ	8927	9781	9976	10026	12975	13399	13401	13402	13406	13408
3933	.....	−21·4	.....	+ 1·9	−33·4	−28·8	−22·1	.....	+ 4·7	.....
Hε	−13·9	−18·8	.....	+10·4	−30·5	.....	−24·8	.....	.....	.....
4009	.....	−17·5	−23·2	.....	−29·9	.....	.....	.....	.....	.....
4026	−10·7	.....	−23·2	+ 8·4	−26·9	−31·5	−23·5	−20·9	−1 ·6	
Hδ	−18·9	− 9·5	−16·2	+ 9·0	−34·8	−26·7	−24·0	−18·8	−5 ·1	−16·9
4120	.....	.....	.....	.....	.....	−34·5	.....	.....	.....	−24·4
4143	.....	.....	−17·2	.....	−28·7	.....	.....	− 8·5	.....	−28·5
4267	−14·7	.....	.....	.....	−27·9	−22·5	.....	−23·2	.....	−14·4
Hγ	−18·7	−11·2	−16·5	+ 8·3	−23·8	−28·8	−22·8	−16·6	+ 3·7	−18·8
4387	− 9·5	.....	−21·8	−11·8	−27·6	−28·3	−15·7	− 9·4	.....	−14·4
4471	−19·1	−20·0	−25·5	− 3·7	−30·9	−30·3	.....	−27·9	− 6·7	−29·8
4481	.....	.....	.....	− 6·1	−32·1	−29·2	−24·6	−24·6	−23·3	−14·7
4713	.....	.....	.....	.....	.....	.....	−21·4	.....	.....	.....
Hβ	−18·8	−16·8	−17·3	+ 5·6	−25·8	−27·4	−16·1	−27·1	− 0·5	−20·0
4921	−10·4	.....	.....	.....	.....	.....	.....	.....	.....	.....
Weighted Mean Velocity.....	−15·7	−15·5	−18·4	+ 5·7	−26·1	−28·4	−21·8	−20·4	− 0·7	−20·3

Plate / λ	13413	13419	13421	13425	13435	13444	13452	13461	13468	13526
3933	−22·5	−19·2	− 2·7	+ 0·1	− 7·9	−29·8	.....	.....	+ 7·0	+ 5·6
Hε	−23·5	−14·9	.....	− 1·0	.....	−28·0	.....	.....	+11·1	.....
4009	−22·3	.....	+ 0·4	+ 5·7	.....	.....	−17·5	−22·5	.....	.....
4026	−21·6	− 6·9	− 9·8	+13·2	− 9·1	−19·2	−22·4	−27·4	+10·0	+14·4
Hδ	−17·8	−22·6	+ 2·2	− 2·0	− 7·0	−20·4	.....	.....	.....	+10·9
4120	−30·8	.....	.....	.....	.....	.....	.....	.....	.....	.....
4143	.....	− 6·1	.....	+11·5	.....	.....	.....	.....	+ 4·3	.....
4267	.....	.....	.....	.....	.....	−26·1	.....	−26·4	.....	.....
Hγ	−19·5	−16·1	− 5·9	+ 2·2	− 5·8	−25·7	−24·7	−25·1	+14·8	+13·3
4387	−16·6	−16·2	− 3·6	+16·4	.....	−23·0	−19·8	− 8·9	+ 0·3	+12·0
4471	.....	−19·6	+ 3·5	+ 4·9	− 6·1	−20·2	−29·1	−28·5	+ 3·4	+11·2
4481	.....	−21·9	− 5·2	+13·9	− 7·2	−26·9	−25·8	−24·1	+ 4·1	.....
4713	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hβ	−21·3	−25·8	+ 1·3	+ 1·4	− 6·8	−28·9	.....	.....	− 3·5	+ 8·8
4921	.....	.....	.....	.....	.....	.....	.....	.....	.....	− 2·9
Weighted Mean Velocity.....	−20·1	−18·3	− 2·0	+ 6·0	− 6·7	−25·2	−24·9	−24·1	+ 7·4	+ 9·8

TABLE II—LINE VELOCITIES IN KAPPA DRACONIS—Concluded

λ \ Plate	13528	13531	13534	13537	13540	13565	13587	13590	13600	13602
3933	+ 3·4	− 3·1	− 6·0	− 7·3	−12·8	− 5·2	−13·6	−13·3	.....	−25·7
Hε	.....	.....	.....	− 7·2	.....	− 2·7	−10·4	.....	−23·2	−42·2
4009	.....	.....	.....	.....	.....	−11·1	.....	.....	.....	−44·1
4026	+ 9·6	− 3·2	+ 2·5	− 2·3	−15·2	− 3·1	−12·8	−14·4	.....	−27·9
Hδ	+ 5·7	+ 3·2	+ 2·4	− 5·9	− 8·7	− 8·6	−16·8	−18·1	−27·2	−38·2
4120	.....	+ 0·1	.....	.....	.....	.....	.....	.....	.....	.....
4143	+ 3·8	.....	.....	.....	− 6·8	.....	.....	−11·3	−17·4	−32·2
4267	.....	.....	.....	−14·7	.....	.....	−13·3	−21·0	−43·9	−19·9
Hγ	+ 2·1	+ 4·2	0·0	− 1·9	−11·0	− 3·0	− 6·2	−14·4	−21·4	−21·4
4387	+ 3·6	+ 1·5	.....	−14·1	.....	− 2·8	−14·9	−19·7	.....	−26·9
4471	+ 6·9	− 1·0	+ 2·2	+ 1·1	−10·9	+ 3·2	− 9·0	−19·2	−24·6	−21·3
4481	+ 6·8	+ 6·8	.....	.....	− 9·8	+ 5·4	−18·1	−17·1	−32·5	−16·9
4713	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hβ	− 2·2	+ 0·5	+ 1·4	− 4·0	−10·5	− 4·2	−10·7	−20·2	−32·5	−26·9
4921	.....	− 1·8	.....	+ 3·4	.....	.....	−12·3	.....	.....	.....
Weighted Mean Velocity.....	+ 4·1	+ 2·1	− 0·2	− 4·0	−11·5	− 3·4	−11·9	−16·4	−28·7	−27·7

λ \ Plate	13605	13609	13611	13627	13641	13674	13691	13709
3933	−33·5	−21·1	−12·6	+12·8	+ 7·5	−27·9	−30·8	+ 1·8
Hε	.....	−17·8	−13·5	.....	+ 6·6	−17·1	.....	+ 5·2
4009	.....	.....	.....	.....	+11·6	.....	.....	+ 7·1
4026	−30·8	−13·0	−12·1	+ 8·7	+15·5	−18·3	−24·0	+13·0
Hδ	−22·6	−12·6	−11·4	+17·3	+ 4·0	−17·9	.....	+ 4·9
4120	.....	.....	.....	.....	.....	.....	.....	.....
4143	.....	.....	− 1·8	.....	.....	−18·5	.....	.....
4267	.....	−12·6	−21·2	.....	.....	.....	−25·9	.....
Hγ	−25·2	−27·9	− 8·7	+ 4·4	+ 3·7	−26·0	−26·8	+ 4·3
4387	.....	.....	−12·8	.....	.....	.....	−25·2	.....
4471	−36·5	−21·9	−13·0	+ 8·0	− 3·9	−21·4	−32·9	+ 1·1
4481	−21·1	−24·1	− 6·4	+10·3	+ 6·1	.....	.....	.....
4713	.....	.....	.....	.....	.....	.....	−29·1	.....
Hβ	−28·1	−20·9	− 9·7	− 2·8	+ 8·7	−22·7	−28·1	+ 4·8
4921	−34·5	.....	−11·1	− 8·3	.....	−27·5	.....	.....
Weighted Mean Velocity.....	−28·1	−20·2	−10·6	+ 6·5	+ 5·8	−22·9	−27·8	+ 5·6

It seems indisputable, from the run of these measures which show remarkably small accidental errors for a B-type spectrum of this character, that all the lines give the same velocity. There are no systematic differences between Hβ and 4471 nor between the measures of the hydrogen and the other absorption lines and, further, Ca K gives the same velocity as the other absorption lines. While it is possible that variation in the character of the spectrum may account for the different results at Ann Arbor and Victoria, it seems

obvious from the internal agreement of the measures, confirmed by the small probable error for a single plate for a B-type star of $\pm 1 \cdot 7$ km. per second obtained from the orbit, that the Victoria results correctly represent the nature of the spectrum from 1923 to 1926.

When the measures showed that the Victoria plates could not be made to agree with Baker's curve and that his period was probably in error, trials were made of all likely periods. After different submultiples of the original period had been tested it was found that a period of 0·89038 days, slightly less than one-tenth of Baker's period, satisfied all the Victoria observations and that the Yerkes observations dating back to 1902 and given in Table III were also in agreement. That this is the correct period can scarcely be doubted from the run of six plates obtained on June 15 by Mr. J. A. Pearce and the writer, and of two and three plates per night obtained on June 25, 26, 28, where the short period character of the variation is clearly shown. Further, the very small residuals for a B-type star from the final orbit, given in the seventh column of Table I, would not be possible for an erroneous period of so short a duration. The final proof is furnished by the agreement of all the Yerkes observations between 1902 and 1925 given in Table III below and represented by open circles on the accompanying velocity curve.

TABLE III—YERKES OBSERVATIONS OF KAPPA DRACONIS

Date	Julian Day 2,410,000·000+	Phase from J.D. 2,424,650·000	Velocity	Residuals O–C
1902 Feb. 3	5,784·824	·338	−28·6	− 7·2
Sept. 13	6,006·597	·406	+ 4·7	+13·7
1904 Jan. 23	6,503·919	·006	− 7·1	+10·2
Dec. 30	6,845·924	·105	−23·5	+ 1·5
1911 Jan. 2	9,039·925	·209	−27·0	+ 2·2
1919 Dec. 29	12,322·978	·431	− 7·5	− 2·0
1920 Jan. 9	12,333·592	·361	− 7·2	+10·4
Feb. 20	12,375·919	·840	−18·0	− 6·0
April 5	12,420·747	·259	−23·6	+ 4·8
1925 Feb. 12	14,193·655	·420	− 3·6	+ 3·2
" 12	14,193·689	·454	− 2·9	− 1·8

The Victoria observations, after the period was obtained, were grouped into the following 17 normal places which were weighted according to the number of plates in the normal place, each single plate being given unit weight.

TABLE IV—NORMAL PLACES OF KAPPA DRACONIS

Number	Mean Phase from 2,424,650·000	Mean Velocity	Number of Plates	Wt.	Residuals	
					Prel.	Final
1	·002	−15·7	1	1	+1·8	+1·2
2	·059	−21·5	2	2	+0·3	0·0
3	·110	−25·0	2	2	−0·2	+0·2
4	·179	−28·3	3	3	−0·8	+0·4
5	·239	−27·9	2	2	+0·1	+1·4
6	·315	−26·1	1	1	−1·5	−1·2
7	·353	−21·1	4	4	−0·4	−1·2
8	·371	−19·4	2	2	−1·2	−2·4
9	·382	−13·0	2	2	+3·5	+1·9
10	·446	− 2·7	2	2	+2·2	0·0
11	·513	+ 7·3	3	3	+1·3	+1·1
12	·616	+ 5·2	3	3	−2·8	−1·8
13	·655	+ 5·2	3	3	−0·1	+0·6
14	·729	− 0·4	2	2	+1·5	+1·2
15	·790	− 5·4	2	2	+2·8	+2·0
16	·825	−11·7	2	2	−0·1	−1·0
17	·876	−18·4	2	2	−2·2	−2·9

Preliminary elements were obtained by the usual graphical method from these normal places and are given in Table VI below. A least-squares correction to these preliminary elements omitting the period as sufficiently determined over the long interval of observation, was carried through by Lehmann-Filhés method. The following substitutions were made for homogeneity.

$$\begin{aligned} \mathrm{v} &= \delta\gamma \\ \mathrm{w} &= \delta\mathrm{K} \\ \mathrm{x} &= \mathrm{K}\delta e \\ \mathrm{y} &= \mathrm{K}\delta\omega \\ \mathrm{z} &= \frac{\mathrm{K}\mu\delta\mathrm{T}}{(1-e^2)^{\frac{3}{2}}} \end{aligned}$$

and the following observation equations, Table V, were formed.

TABLE V—OBSERVATION EQUATIONS OF KAPPA DRACONIS

10	1·000v	+0·355w	−0·224x	+1·135y	−1·367z	−2·2 = 0	Wt. 2
11	1·000	+0·936	+1·022	+0·735	−0·805	−1·3	3
12	1·000	+1·046	−0·183	−0·201	+0·400	+2·8	3
13	1·000	+0·895	−0·718	−0·461	+0·609	+0·1	3
14	1·000	+0·511	−0·968	−0·754	+0·735	−1·5	2
15	1·000	+0·178	−0·622	−0·834	+0·711	−2·8	2
16	1·000	−0·005	−0·316	−0·829	+0·673	+0·1	2
17	1·000	−0·250	+0·162	−0·767	+0·604	+2·2	2
1	1·000	−0·322	+0·307	−0·736	+0·580	−1·8	1
2	1·000	−0·548	+0·732	−0·585	+0·481	−0·3	2
3	1·000	−0·712	+0·951	−0·398	+0·371	+0·2	2
4	1·000	−0·856	+0·877	−0·074	+0·172	+0·8	3
5	1·000	−0·880	+0·395	+0·267	−0·084	−0·1	2
6	1·000	−0·700	−0·633	+0·743	−0·581	+1·5	1
7	1·000	−0·490	−1·054	+0·960	−0·896	+0·4	4
8	1·000	−0·359	−1·138	+1·044	−1·045	+1·1	2
9	1·000	−0·269	−1·135	+1·087	−1·132	−3·5	2

From these were obtained the normal equations:

38·000v	− 0·877w	− 5·874x	+ 2·576y	− 2·563z	− 5·1 =0
	+16·594	− 2·344	− 2·247	+ 2·340	− 1·784
		+23·385	− 5·562	+ 5·145	+ 6·504
			+20·518	−20·182	− 7·671
				+20·475	+11·868

resulting in corrections as follows:

v	=	+0·0705	$\delta\gamma$	=	+0·07 km.
w	=	+0·1708	δK	=	+0·17 km.
x	=	−0·2685	δe	=	−0·0144.
y	=	−6·6993	$\delta\omega$	=	−20°·53
z	=	−7·1266	δT	=	−0·0508 days

The final values with their probable errors are given in Table VI.

TABLE VI—ELEMENTS OF KAPPA DRACONIS

Elements	Preliminary	Final
P = Period	P = 0·89038 days	P = 0·89038 days
e = Eccentricity	e = 0·20	e = 0·186 ±0·020
K = Semi-amplitude	K = 18·7 km.	K = 18·87 ±0·43 km.
γ = Velocity of system	γ = −11·5 km.	γ = −11·43 ±0·28 km.
ω = Longitude of apse	ω = 305°	ω = 284°·47 ±6°·70
T = Time of periastron	T = J.D. 2,424,650·480 days	T = J.D. 2,424,650·4292 days ±0·0155
		$a \sin i$ = 227,000 km.

This solution reduced Σpvv from 104 to 76, a reduction of 27 per cent, the agreement between the residuals from the ephemeris and the observation equations is satisfactory while the probable error of a single plate has the very low value for a single-prism observation of a B-type star of ±1·7 km. The good agreement between the Victoria observations, represented by filled circles on the accompanying velocity curve, and the final orbit and the possibility of being able to fit 38 observations well distributed over the cycle into a curve of such short period seems sufficient evidence of the accuracy of the period and the reliability of the elements. When to this is added the fact that all of the eleven Yerkes observations, obtained in the years 1902, 1904, 1911, 1919, 1920 and 1925 with a total separation of over 10,000 revolutions between the first Yerkes and the last Victoria observation, satisfactorily fit our short period curve with a probable error per plate of ±4·9 km. per second, much less than the average probable error ±9·0 km. of Struve's recent measures,[4] there can be no reasonable doubt of the accuracy of the Victoria orbit. Further,

in view of the agreement between the velocities of the hydrogen lines, the helium and other B-type lines, and the Ca K line, there seems no reason to assume a complex system for κ Draconis or that it is anything but a straightforward spectroscopic binary with only one spectrum visible.

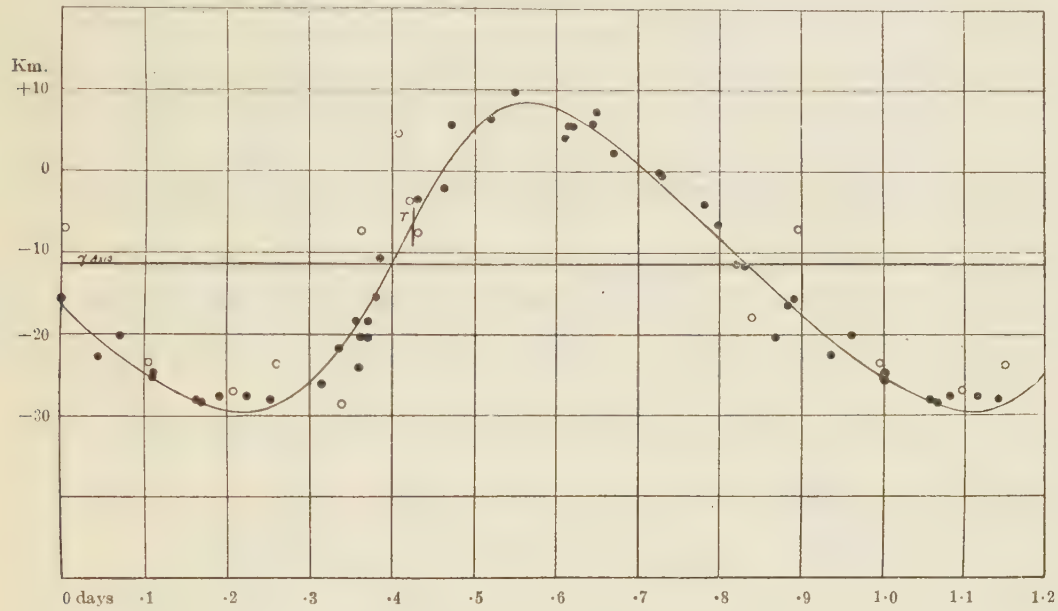

FIG. 1—VELOCITY CURVE OF KAPPA DRACONIS

Single Observations, Victoria ● Single Observations, Yerkes ○

The writer has much pleasure in gratefully acknowledging the assistance of the Director in the discussion and for suggestions by Mr. Harper and Mr. Pearce in connection with the orbital work.

REFERENCES

[1]Annals H.C.O. *28*, 105.
[2]L.OB. *7*, 170.
[3]Pub. Mich. Univ. Obs., *3*, 29.
[4]Ap. J. *64*, 1, 1926.

Dominion Astrophysical Observatory,
Victoria, B.C.
September, 1926.

H.D. 214240

The star H.D. 214240, R.A. $22^h\ 31^m.\ 8$, Dec. $+49°\ 33'$ (1900), visual magnitude 6·20, spectral type by H.D. Catalogue B3, is one of the stars in the B-type programme under observation here. The binary character of this star has not been hitherto announced. The plates of this star were handed over by the director to the writer for an investigation of the spectrum and the computation of the orbit. The first plate obtained on July 2, 1925 showed double lines but the secondary spectrum is faint and the relative intensity of spectral lines of the primary as compared with those of the secondary is about 3 to 1. Only at the nodes, where the separation is about 200 km., could the secondary be measured with any degree of accuracy.

As stated above the spectral type is given in the H.D. Catalogue as B3. The 32 plates used in the orbit were carefully examined and on account of the presence of the oxygen triplet λλ4070, 4072 and 4075, showing on some of the plates, although faint, the type of the primary seems somewhat earlier than B3 and has been classified as B2·5.

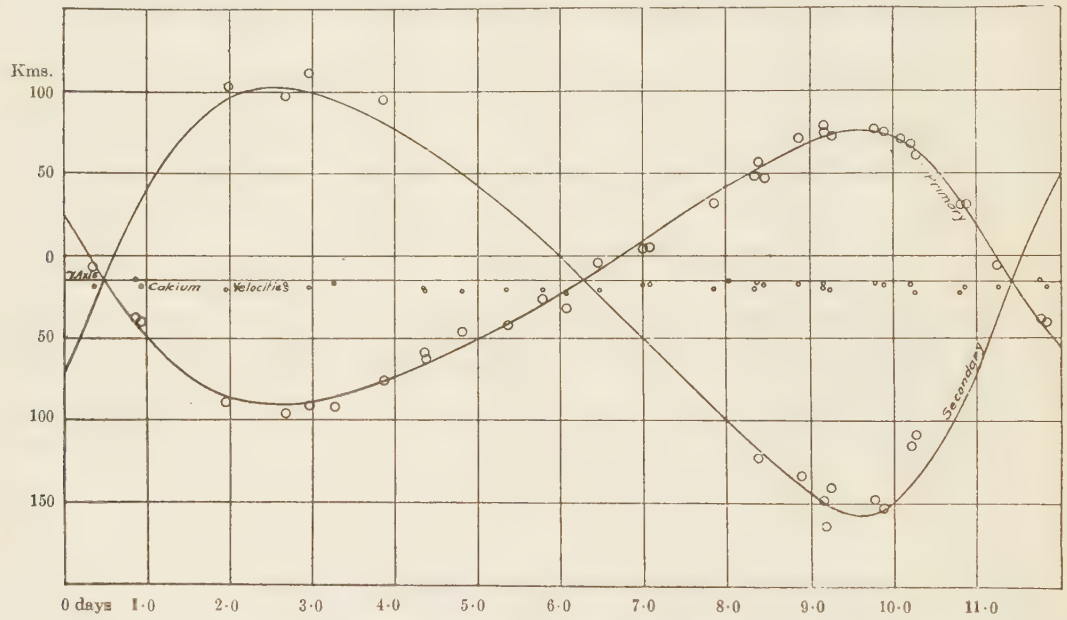

Fig. 2—Velocity Curves of H.D. 214240.

Secondary Spectrum

The SiII lines λλ4128 and 4131 were measured on several plates at the nodes and the velocities of these lines agree very well with those of the other lines of the secondary spectrum which indicates that its type is B5 or later. Again the relative intensity of the helium line λ4471 to the Mg. line λ4481 was used as a criterion of the type and a careful comparison of these lines on the micrometer engine showed them, on the whole, to be equal. In view of this, the secondary spectrum has been classified as B8. The lines in this spectrum are weak and difficult of measurement. The probable error of a single plate of weight unity is ±9·2 km. per second, while that of the primary where the lines are fair, is ±3·2 km. per second. On account of the poor quality of the lines of the second-

ary spectrum the writer did not include it in the least-squares solution of the primary. However, corrections for K_2 were obtained by accepting the elements from the primary solution and obtaining by least-squares the most probable correction for K_2. The solution of the primary reduced Σpvv from 515 to 398, a reduction of approximately 23 per cent.

The mean velocity of the H and K lines of calcium is $-18\cdot9 \pm 0\cdot3$ km. per second, while the probable error of a measure is $\pm 1\cdot6$ km. The lines are good and as the velocity indicates, do not oscillate with the star. Figure 2 shows the individual calcium velocities and those of the primary and secondary spectrum plotted on the final velocity curve.

The component of the solar motion in the direction of this star is $-11\cdot8$ km. per second giving a residual velocity of $-7\cdot1$ km. per second for the calcium cloud.

The 32 spectra employed in the orbit are given in Table I below, which contains the Greenwich and Julian dates, final phases, the observed velocities, the residuals and the calcium velocities. The final phases are reckoned from the final value of periastron passage using the corrected period 10·9114 days.

TABLE I—OBSERVATION OF H.D. 214240

Plate	Date G.C.T.	Julian Date 2,424,000+	Final Phase	Observed Velocities		Residuals		Calcium Velocity
				Prim.	Sec.	Prim.	Sec.	
11816	1925 July 2.....	333·964	4·333	−57·9	.....	+8·2	.....	−20·1
12065	Aug. 6.....	368·833	6·468	− 4·8	.....	+4·2	.....	−18·4
12232	Sept. 7.....	400·881	5·782	−27·0	.....	−1·0	.....	−20·8
12263	" 13.....	406·930	0·920	−39·5	.....	+5·6	.....	−15·0
12302	" 17.....	410·816	4·806	−46·4	.....	+8·6	.....	−22·0
12378	" 25.....	418·887	1·965	−89·4	+104·2	−2·7	+ 7·5	−20·6
12530	Oct. 14.....	437·716	9·883	+74·2	−152·6	+0·2	0·0	−18·7
12534	" 15.....	438·637	10·804	+30·9	.....	+0·9	.....	−22·7
12554	" 22.....	445·745	7·000	+ 4·4	.....	−4·4	.....	−17·6
12560	" 23.....	446·592	7·847	+31·3	.....	−5·9	.....	−20·3
12582	Nov. 1.....	455·736	6·080	−31·5	.....	−8·5	.....	−22·3
12593	" 2.....	456·734	7·078	+ 4·5	.....	−6·9	.....	−16·4
12607	" 4.....	458·833	9·177	+74·7	−164·9	+2·7	−13·5	−16·6
12660	" 26.....	480·635	9·156	+79·3	−147·8	+7·1	+ 2·2	−20·6
12689	Dec. 3.....	487·739	5·349	−41·5	.....	+0·3	.....	−21·0
12692	" 28	512·588	8·375	+56·0	−123·2	+3·7	− 4·2	−15·0
12744	1926 Jan. 8.....	523·591	8·467	+46·4	.....	−8·6	.....	−16·7
13654	July 2.....	698·945	9·238	+73·6	−140·9	−0·5	+11·1	−21·1
13671	" 3.....	699·976	10·269	+61·1	−107·8	−0·9	+27·2	−22·6
13682	" 4.....	700·954	0·336	− 5·7	.....	−1·7	.....	−19·5
13717	" 8.....	704·964	4·346	−63·4	.....	+2·6	.....	−22·2
13770	" 12.....	708·951	8·333	+47·9	.....	−3·1	.....	−20·1
13778	" 14.....	710·817	10·199	+66·1	−114·7	+1·1	+24·3	−17·0
14002	Aug. 19.....	746·931	2·667	−95·4	+ 96·9	−5·4	− 5·1	−16·5
14341	Oct. 19.....	807·694	8·873	+70·2	−133·6	+5·0	+ 6·4	−17·1
14348	" 20.....	808·598	9·777	+75·6	−147·4	+0·6	+ 7·6	−16·1
14362	" 20.....	808·884	10·063	+69·7	.....	+0·7	.....	.....
14373	" 22.....	810·594	0·862	−38·3	.....	+3·7	.....	−14·8
14394	" 25.....	813·583	3·851	−76·4	+ 96·7	+0·6	+15·7	.....
14446	Nov. 1.....	820·581	10·849	+30·1	.....	+ 1·1	.....	−18·5
14520	" 4.....	823·600	2·956	−92·0	+111·5	− 3·0	+11·5	−19·9
14530	" 4.....	823·888	3·243	−91·9	.....	− 5·9	.....	−15·9

The observations, after the approximate period of 10·91 days was selected, were grouped into the following 21 normal places. The grouping was arranged so that a normal place included only a small number of revolutions and thus the result is practically the same as if the individual observations had been treated separately. The normal places were weighted according to the number of plates in the normal place, each single plate being given weight unity.

TABLE II—NORMAL PLACES OF H.D. 214240

Number	Mean Phase from E 4333·000	Mean Velocity		Weight		Primary Residuals	
		Prim.	Sec.	Prim.	Sec.	Prelim.	Final
1	0·543	−76·4	+96·7	1	1	∓ 0·38	+0·2
2	0·964	−57·9	.....	1	.....	+10·38	+8·75
3	1·024	−63·4	.....	1	.....	+ 3·60	+3·12
4	1·722	−43·9	.....	2	.....	+ 6·10	+5·13
5	2·574	−29·2	.....	2	.....	− 2·92	−3·57
6	3·491	+ 1·4	.....	3	.....	− 1·22	−1·05
7	4·492	+31·3	.....	1	.....	− 5·57	−3·60
8	5·011	+47·9	.....	1	.....	− 6·14	−2·74
9	5·074	+51·2	−123·2	2	1	− 4·88	−2·02
10	5·740	+71·9	−137·2	2	2	− 1·69	+2·03
11	5·814	+77·0	−156·3	2	2	+ 1·96	+5·21
12	6·526	+74·2	−152·6	1	1	− 2·20	+0·08
13	6·611	+72·6	−147·4	2	1	− 2·18	−0·94
14	6·912	+63·6	−111·2	2	2	− 1·15	−1·36
15	7·447	+30·9	.....	1	.....	− 1·21	−1·77
16	7·541	+30·1	.....	1	.....	+ 5·22	+0·78
17	7·924	− 5·7	.....	1	.....	+ 0·44	−3·38
18	8·464	−38·3	.....	1	.....	+ 7·45	+3·65
19	8·470	−39·5	.....	1	.....	+ 6·68	+6·20
20	9·517	−89·4	+117·8	1	1	− 2·85	−3·32
21	10·556	−93·1	+104·2	3	2	− 3·83	−4·35

Preliminary elements were obtained by the usual method from these normal places and are given in Table IV below. As no previous observations existed it was considered advisable to include the period in the least-squares solution to these preliminary elements. This solution was carried through by Lehmann-Filhés method. The following substitutions were made for homogeneity:

$$u = \delta\gamma$$
$$v = \delta K$$
$$w = K\delta e$$
$$x = -K\,\delta\omega$$
$$y = \frac{K\mu\,\delta T}{(1-e^2)^{\frac{3}{2}}}$$
$$z = \frac{100K}{(1-e^2)^{\frac{3}{2}}}\,\delta\mu$$

and the following observation equations, Table III, were formed.

TABLE III—OBSERVATION EQUATIONS OF H.D. 214240

1	1·000u	−0·725v	+0·971w	−0·329x	−0·344y	−1·628z	− 0·38 = 0	Wt.1
2	1·000	−0·625	+0·906	−0·455	−0·402	+0·026	−10·38	1
3	1·000	−0·610	+0·889	−0·471	−0·410	−1·494	− 3·60	1
4	1·000	−0·410	+0·593	−0·629	−0·484	−0·527	− 6·10	2
5	1·000	−0·131	+0·067	−0·745	−0·554	−0·487	+ 2·92	2
6	1·000	+0·209	−0·550	−0·768	−0·615	−0·512	+ 1·22	3
7	1·000	+0·612	−0·982	−0·635	−0·634	−0·673	+ 5·57	1
8	1·000	+0·814	−0·893	−0·479	−0·591	−2·178	+ 6·14	1
9	1·000	+0·838	−0·906	−0·454	−0·580	−1·030	+ 4·88	2
10	1·000	+1·044	−0·319	−0·118	−0·359	−1·482	+ 1·69	2
11	1·000	+1·061	−0·216	−0·070	−0·317	−0·410	− 1·96	2
12	1·000	+1·077	+0·848	+0·465	+0·319	+0·310	+ 2·20	1
13	1·000	+1·058	+0·944	+0·534	+0·420	+1·967	+ 2·18	2
14	1·000	+0·940	+1·102	+0·779	+0·812	+2·963	+ 1·15	2
15	1·000	+0·556	+0·488	+1·120	+1·395	+1·369	+ 1·21	1
16	1·000	+0·471	+0·281	+1·158	+1·452	+6·971	− 5·22	1
17	1·000	+0·106	−0·581	+1·227	+1·503	+5·418	− 0·44	1
18	1·000	−0·360	−1·192	+1·112	+1·173	+5·514	− 7·45	1
19	1·000	−0·365	−1·196	+1·109	+1·166	+0·775	− 6·68	1
20	1·000	−0·840	−0·260	+0·553	+0·309	+0·242	+ 2·85	1
21	1·000	−0·872	+0·754	+0·017	−0·151	−0·691	+ 3·83	3

From these were obtained the normal equations:

32·000u +	6·922v	+ 2·421w	+ 0·716x	+ 0·514y	+13·031z	+ 8·49 = 0
	+17·620	− 2·196	+ 2·184	+ 1·308	+ 8·460	+29·936
		+18·084	+ 1·772	+ 1·728	+ 3·725	− 9·169
			+14·165	+14·391	+36·813	−17·986
				+15·534	+41·888	−26·125
					+156·458	−97·689

resulting in corrections as follows:—

u	=	−0·1621	$\delta\gamma$	=	−0·16 km.
v	=	−1·7297	δK	=	−1·73 km.
w	=	+0·2177	δe	=	+0·003
x	=	−3·7733	$\delta\omega$	=	+2°·5435
y	=	+3·4234	δT	=	+0·0635
z	=	+0·6975	$\delta\mu$	=	−0·000074485
			δP	=	+0·001411 days

The final values with their probable errors are given in Table IV.

TABLE IV—ELEMENTS OF H.D. 214240

Element	Preliminary	Final
P = Period	10·91 days	10·9114 ± 0·00126 days
e = Eccentricity	0·25	0·253 ± 0·012
K_1 = Semi-amplitude primary	85 km	83·27 ± 0·93 km.
K_2 = Semi-amplitude secondary	124 km	129·44 ± 3·59 km.
γ = Velocity of system	−15·12	−15·28 ± 0·70 km.
ω_1 = Longitude of apse	65°	67°·54 ± 2°·97
ω_2 = Longitude of apse	245°	247°·54 ± 2°·97
T = Time of periastron	J.D. 2,424, 340·478	J.D. 2,424,340·5415 ± 0·0937
$a_1 \sin i$ = Semi axis major primary		12,088,000 km.
$a_2 \sin i$ = Semi axis major secondary		18,789,000 km.
$m_1 \sin^3 i$ = Mass primary		6·01 ⊙
$m_2 \sin^3 i$ = Mass secondary		3·87 ⊙

Considering the spectral type of H.D. 214240 as B2·5 for the primary and interpolating from Fowler and Milne's[1] scale, a temperature of 17,500°K has been assigned to it. The spectral lines of the brighter component of the star under discussion have been compared with those of U Herculis, a B3 star whose photometric orbit [2] has been obtained and whose density is given as 0·097 for the primary. The spectra of the primaries of these two stars are very similar in appearance and are not unlike in mass, U Herculis being 7·5⊙ while the minimum mass of H.D. 214240 is 6·01⊙ and with average inclination is 9·25⊙. Using a temperature 17,500°K mentioned above a surface brightness by Hertzsprung's method[3] of −3·24 magnitudes, 19·76 times the sun, has been computed. On account of the high eccentricity of H.D. 214240, viz. 0·253, the star has probably had a considerable advance in its evolutionary stage and it seems reasonable to assume that its density is of the order 0·10. With a surface brightness of −3·24 magnitudes compared with the sun and a minimum mass of 6·01 times the sun, the absolute magnitude is calculated as −1·86 for a density of 0·05, −1·35 for a density of 0·10 and −1·06 for a density of 0·15. Accepting the spectral type of the secondary as B8 and assigning a temperature of 12,500°K in accordance with Fowler and Milne's[1] scale, the surface brightness is calculated as −2·54 magnitudes, 10·37 times the sun. But the difference of magnitude between a star of mass 6·01 and one of 3·87 times the sun by Eddington's method[4] is 0·71 magnitudes. We have, therefore, two stars of a total visual magnitude of 6·20 differing by 0·71 from which is obtained a magnitude of 6·65 for the brighter and 7·36 for the fainter.

By use of the fundamental equation showing the relation between absolute and apparent magnitude,

$$M = m + 5 + 5 \log \pi$$

where M = absolute magnitude or −1·35

m = apparent magnitude of 6·65

π = parallax

the parallax is computed as 0″·00251 or 1299 light years.

[1]The references will be found on p. 363.

If the average inclination of the orbital plane for H.D. 214240, $\sin^3 i = 0{\cdot}65$, is adopted, the masses become $9{\cdot}25$ and $5{\cdot}95$ times the sun, which for the density, temperature and surface brightness mentioned above, give a parallax of $0''{\cdot}00217$ or 1502 light years.

On the relationship between mass and luminosity by Eddington[4], after applying the temperature term $-2 \log 10 \left(\frac{\text{Te}}{5200}\right)$ the bolometric absolute magnitue for H.D. 214240 is computed as $-2{\cdot}340$ and, after applying the correction for visual magnitudes of $+1{\cdot}50$, the visual magnitude becomes $-0{\cdot}84$ against $-1{\cdot}35$ by the luminosity method. The visual magnitude of $-0{\cdot}84$ corresponds to a density of $0{\cdot}2$. From the above assumptions and computations together with the discussion on H.D. 191201[5] and some recent work on H.D. 1337[6] both made at the Victoria observatory, it would appear that Eddington's theory gives a magnitude somewhat too small for the higher temperature stars, such as the one discussed in this paper.

It may be interesting to ascertain the space velocity of the system of H.D. 214240. In Boss' General Catalogue the proper motion for this star is given as $0''{\cdot}017$ annually after applying corrections in right ascension and declination, which represents a linear tangential velocity of $31{\cdot}7$ km. per second and when combined with the observed radial velocity gives a space velocity of $35{\cdot}2$ km. per second for the system. These computations are based on the minimum mass and resulting parallax of 1299 light years for the system.

References

[1]Fowler and Milne	M.N., *84*, 505, 1924.
[2]U. Herculis, orbit	A.O. *2*, 51, 1910.
[3]Hertzsprung	Mt. W. Cont. *10*, 399.
[4]Eddington	M.N. *84*, 310, 1924
[5]H.D. 191201	Pub. D.A.O. III, No. 11.
[6]H.D. 1337	R.A.S., Aug., Sept. 1925.

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